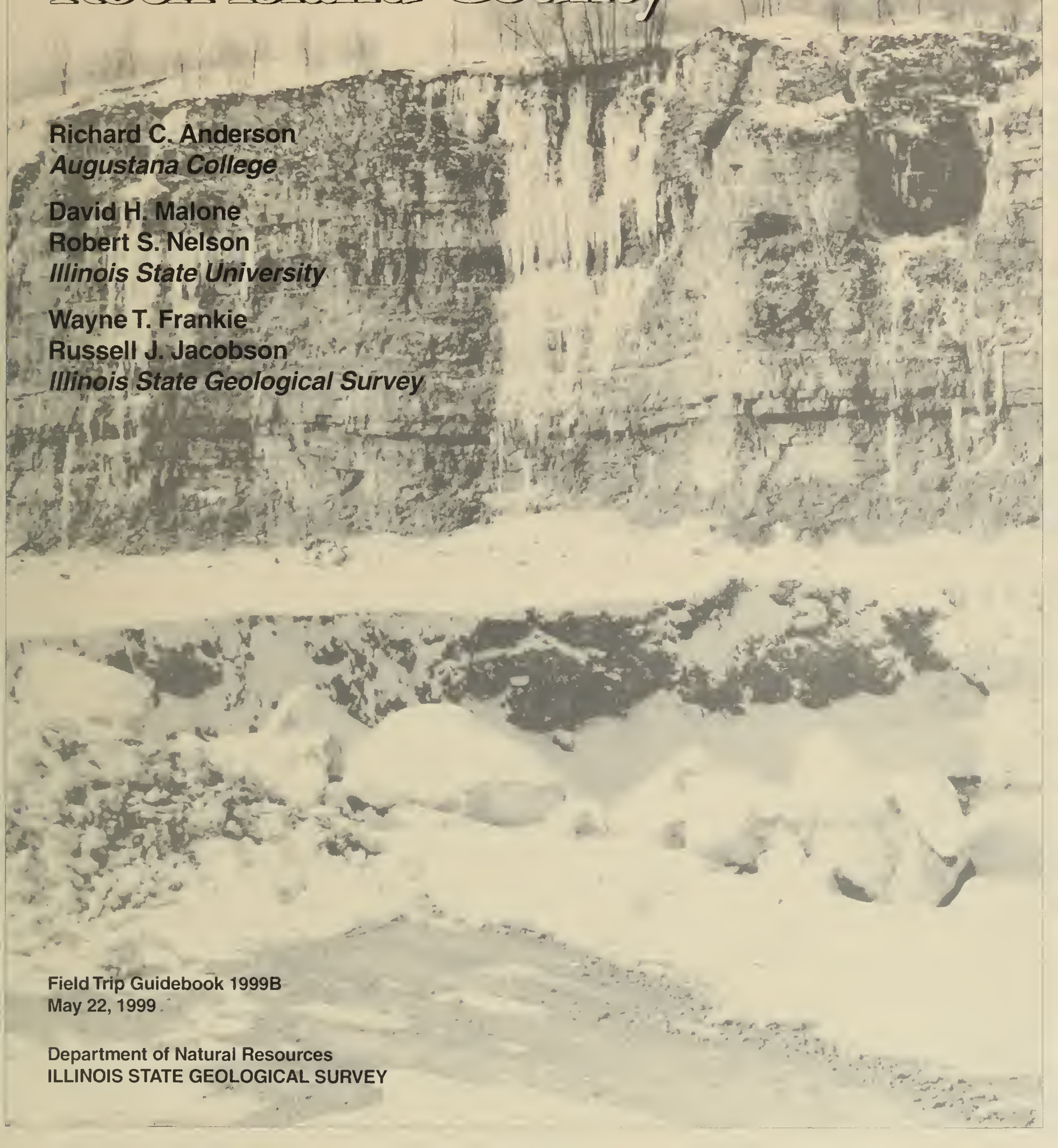
Guide to the Geology of the Rock Island–Milan Area, Rock Island County



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Field Trip Guidebook 1999B
May 22, 1999

Department of Natural Resources
ILLINOIS STATE GEOLOGICAL SURVEY

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Cover photo *Collinson Brothers, Milan Quarry (photo by W.T. Frankie)*

Geological Science Field Trips The Geoscience Education and Outreach unit of the Illinois State Geological Survey (ISGS) conducts four free tours each year to acquaint the public with the rocks, mineral resources, and landscapes of various regions of the state and the geological processes that have formed them. Each trip is an all-day excursion through one or more Illinois counties. Frequent stops are made to explore interesting phenomena, explain the processes that shape our environment, discuss principles of earth science, and collect rocks and fossils. People of all ages and interests are welcome. The trips are especially helpful to teachers preparing earth science units. Grade school students are welcome, but each must be accompanied by a parent or guardian. High school science classes should be supervised by at least one adult for each ten students.

A list of guidebooks of earlier field trips, useful for planning class tours and private outings, can be obtained by contacting the Geoscience Education and Outreach Unit, Illinois State Geological Survey, Natural Resources Building, 615 East Peabody Drive, Champaign, IL 61820-6964. Telephone: (217) 244-2427 or 333-4747.

Two U.S. Geological Survey 7.5-Minute Topographic Quadrangle maps (Coal Valley and Milan) cover this field trip area.

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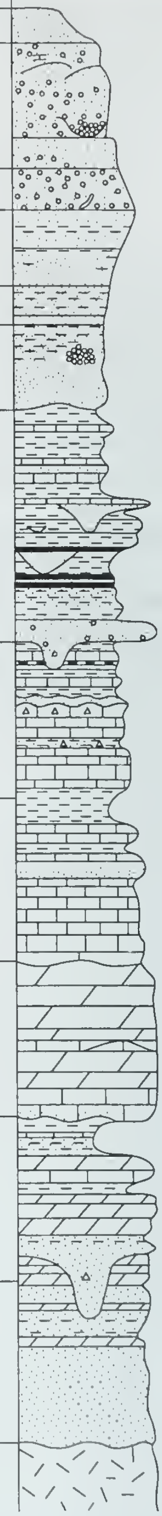
CONTENTS

Era		Period or System and Thickness	Epoch	Age (years ago)	General Types of Rocks
CENOZOIC "Recent Life"	Age of Mammals	Quaternary 0-500'	Holocene	10,000	Recent– alluvium in river valleys
			Pleistocene Glacial Age	1.6 m	Glacial till, glacial outwash, gravel, sand, silt, lake deposits of clay and silt, loess and sand dunes; covers nearly all of state except northwest corner and southern tip
		Tertiary 0-500'	Pliocene	[5.3 m 36.6 m]	Chert gravel, present in northern, southern and western Illinois
			Eocene	57.8 m	Mostly micaceous sand with some silt and clay; presently only in southern Illinois
			Paleocene	66.4 m	Mostly clay, little sand; present only in southern Illinois
MESOZOIC "Middle Life"	Age of Reptiles	Cretaceous 0-300'		[144 m 286 m]	Mostly sand, some thin beds of clay, and, locally, gravel, present only in southern Illinois
PALEOZOIC "Ancient Life"	Age of Amphibians and Early Plants	Pennsylvanian 0-3,000' ("Coal Measures")		320 m	Largely shale and sandstone with beds of coal, limestone, and clay
		Mississippian 0-3,500'		360 m	Black and gray shale at base, middle zone of thick limestone that grades to siltstone chert, and shale; upper zone of interbedded sandstone, shale, and limestone
	Age of Fishes	Devonian 0-1,500'		408 m	Thick limestone, minor sandstones and shales; largely chert and cherty limestone in southern Illinois; black shale at top
	Age of Invertebrates	Silurian 0-1,000'		438 m	Principally dolomite and limestone
		Ordovician 500-2,000'		505 m	Largely dolomite and limestone but contains sandstone, shale, and siltstone formations
		Cambrian 1,500-3,000'		570 m	Chiefly sandstones with some dolomite and shale; exposed only in small areas in north-central Illinois
		Precambrian			Igneous and metamorhpic rocks; known in Illinois only from deep wells



Generalized geologic column showing succession of rocks in Illinois.

ROCK ISLAND–MILAN AREA

The Rock Island, Illinois, area has been the destination for numerous geology field trips and geologic field conferences (for example, Edmunds and Anderson 1967, Anderson and others 1982). This field trip guidebook was developed largely from work published in these field guides. We wish to thank the following for permission to enter their property and help in developing this trip: Moline Consumers Inc., C. E. Peterson and Sons, Collinson Brothers, and the staff at Black Hawk State Historic Site.

This guidebook is divided into four sections. The first section introduces the geology of Illinois and in particular the Rock Island–Milan area. The second section is a road log for the trip, and the third section provides detailed stop descriptions. The final section includes a glossary and supplementary discussions of topics that are important to the field trip area.

GEOLOGIC SETTING

The oldest rocks present in the subsurface (termed basement rocks by geologists) of the field trip area include approximately 1.5-billion-year-old crystalline rocks of the Midcontinent Granite-Rhyolite Terrane (consisting mostly of granitic and rhyolitic igneous, and possibly metamorphic, crystalline rock). Very little is known about these basement rocks because they are not exposed anywhere in Illinois, and few (approximately 35) drill holes have penetrated deep enough to recover samples. From about 1.0 to 0.6 billion years ago, these rocks were exposed and deeply weathered into a landscape similar to that of the present Missouri Ozarks.

The Illinois Basin is the major structural feature of Illinois. This broad elliptical cratonic basin began to develop as a failed arm of Precambrian rifting of North America (figs. 1 & 2). This rifting initially produced the Rough Creek Graben and the Reelfoot Rift in southernmost Illinois. These steep-walled tectonic valleys are filled with sand and gravel that was shed from the adjacent uplands. By the late Precambrian, the rifting had stopped, but the Illinois Basin remained an area of structural weakness prone to infilling of sediment throughout the Paleozoic Era.

During the Paleozoic Era, strata accumulated in seas that covered Illinois and adjacent states. The shallow seas connected with the open ocean to the south during much of the Paleozoic, and the area of southern Illinois was an embayment. The southern part of Illinois and adjacent parts of Indiana and Kentucky sank more rapidly than areas to the north, which allowed a greater thickness of sediment to accumulate there than elsewhere in Illinois. Where stresses built up in places, the relatively thin crust of the earth was periodically flexed and warped to produce both upward bends (anticlines) and downward buckles (synclines). These movements, along with worldwide changes in sea level, produced repeated withdrawals (regressions) and invasions (transgressions) of ocean water across the slowly subsiding region. During the regressions, former sea floors were periodically exposed to erosion, removing some sediments from the rock record. During the Mesozoic Era, the rise of the Pascola Arch in southeastern Missouri and western Tennessee cut off the embayment and separated it from the open sea to the south. Development of the Pascola Arch, combined with the earlier sinking of deeper parts of the area to the north, gave the basin its present asymmetrical, "spoon-shaped" configuration (fig. 3).

Please note: although all present localities have only recently appeared within the geologic time frame, we use the present names of places and geologic features because they provide clear reference points for describing the ancient landscape.

Rock Island County lies along the extreme northwestern margin of the Illinois Basin as defined by the occurrence of Pennsylvanian strata; immediately to the west is the Mississippi River Arch (fig. 2). The regional dip of Paleozoic strata is less than 1° toward the south and southeast. The Precambrian granite and rhyolite lie at a depth of about 4,000 feet beneath the surface in this region. These rocks are unconformably overlain by about 1,900 feet of sandstone and minor amounts of dolomite and shale (Cambrian Mt. Simon through Franconia Formations) followed by 1,800 feet of carbonate rocks, sandstone, and shale (Cambrian Potosi through Devonian Cedar Valley formations) (see fig. 4). The Devonian rocks are unconformably overlain by varying thicknesses of Pennsylvanian shale, sandstone, and coal; and these units are subsequently overlain by Quaternary glacial till, loess, and alluvium. This field trip will examine rocks and sediments that range in age from Silurian through Pleistocene (fig. 5). Rocks older than the Silurian are not exposed at the surface in the field trip area.

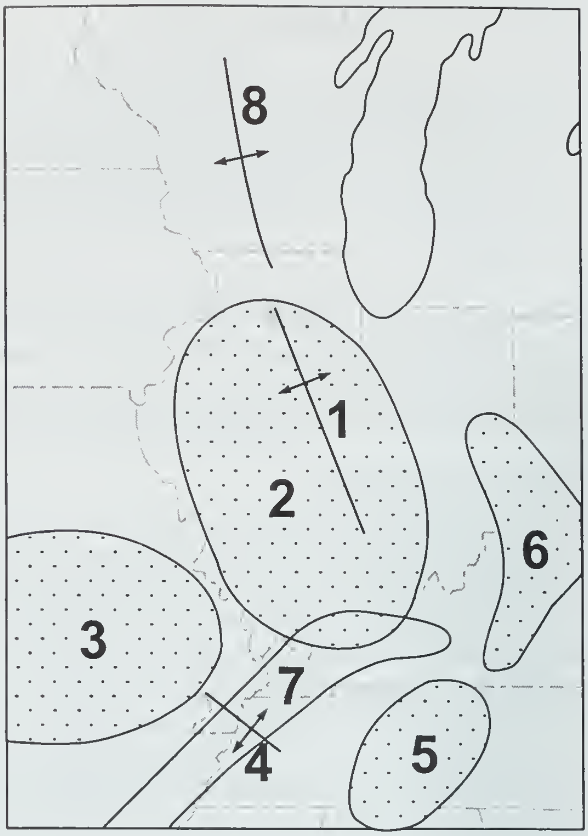


Figure 1 Location of some of the major structures in the Illinois region. (1) La Salle Anticlinorium, (2) Illinois Basin, (3) Ozark Dome, (4) Pascola Arch, (5) Nashville Dome, (6) Cincinnati Arch, (7) Rough Creek Graben-Reelfoot Rift, and (8) Wisconsin Arch.

STRATIGRAPHY

Near the beginning of the Paleozoic Era, about 570 million years ago, the rifting in and near southern Illinois stopped, and the hilly Precambrian landscape began to slowly subside, allowing a shallow sea to invade from the south and southwest. During the several hundred million years of the Paleozoic Era, the area that is now southern Illinois continued to accumulate layers of sediment deposited on the bottom of the shallow seas that repeatedly covered it. The region continued to subside until at least 15,000 feet of strata were deposited. At times the seas withdrew and the deposits were weathered and eroded. As a result, in Illinois there are gaps in the sedimentary record, which are called unconformities. The major gaps form boundaries that separate the Paleozoic rocks into four super sequences: Sauk, Tippecanoe, Kaskaskia, and Absaroka. The major unconformities in the field trip area are shown on figure 4.

Many of the sedimentary units, called formations, have conformable contacts; that is, no significant interruption in deposition occurred as one formation was succeeded by another (figs. 4 & 6). In some instances, even though the composition and appearance of the rocks change significantly at the contact between two formations, the fossils in the rocks and the relationships between the rocks at the contact indicate that deposition was virtually continuous. In contrast however, in some places the top of the lower formation was at least partially eroded before deposition of the next formation began. In these instances, fossils and other evidence in the two formations indicate that there is a significant age difference between the lower unit and the overlying unit. This type of contact is called an unconformity (fig. 6). If the beds above and below an unconformity are parallel, the unconformity is called a disconformity. However, if the lower beds were tilted and eroded prior to deposition of

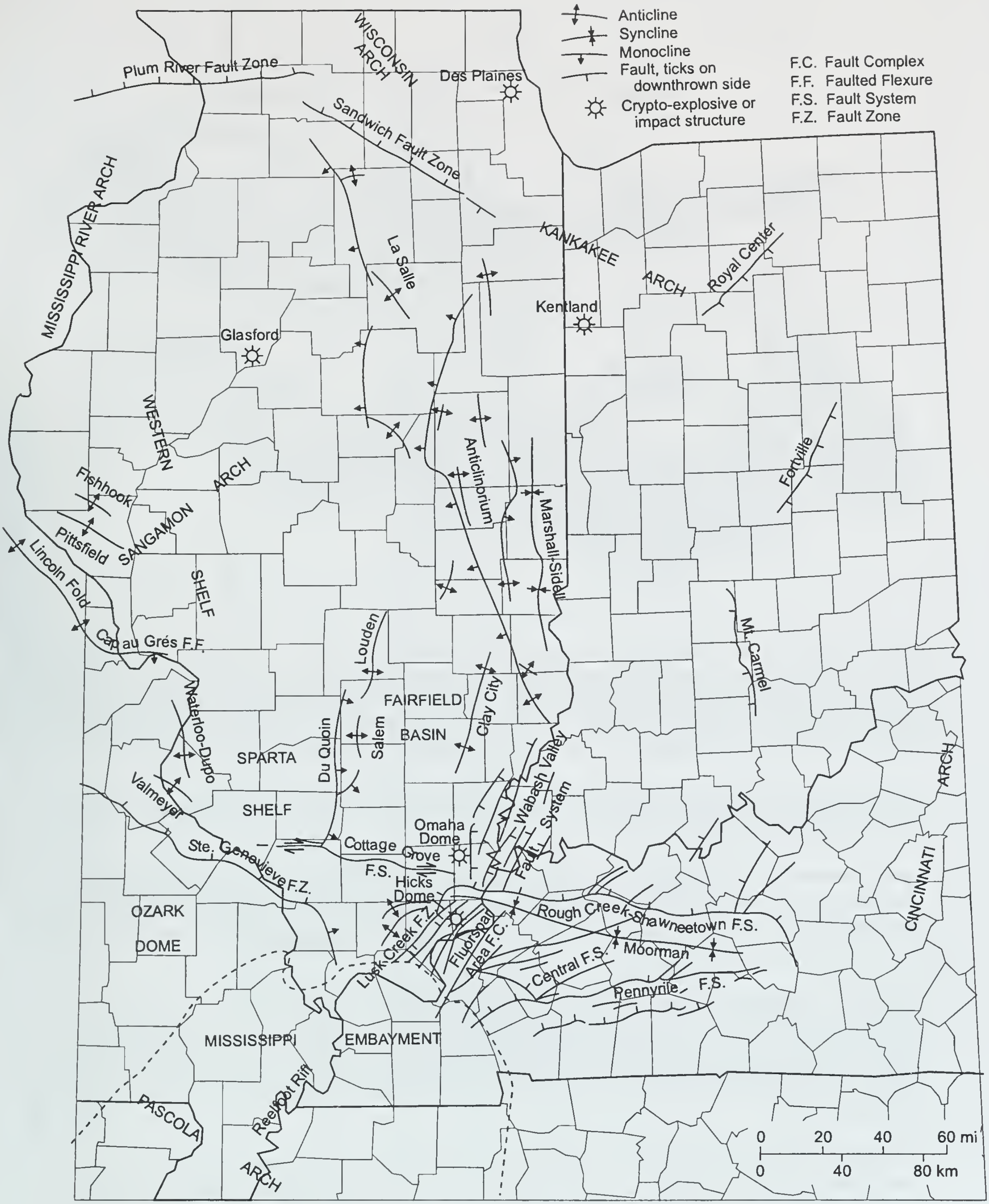


Figure 2 Structural features of Illinois (modified from Buschbach and Kolata 1991).

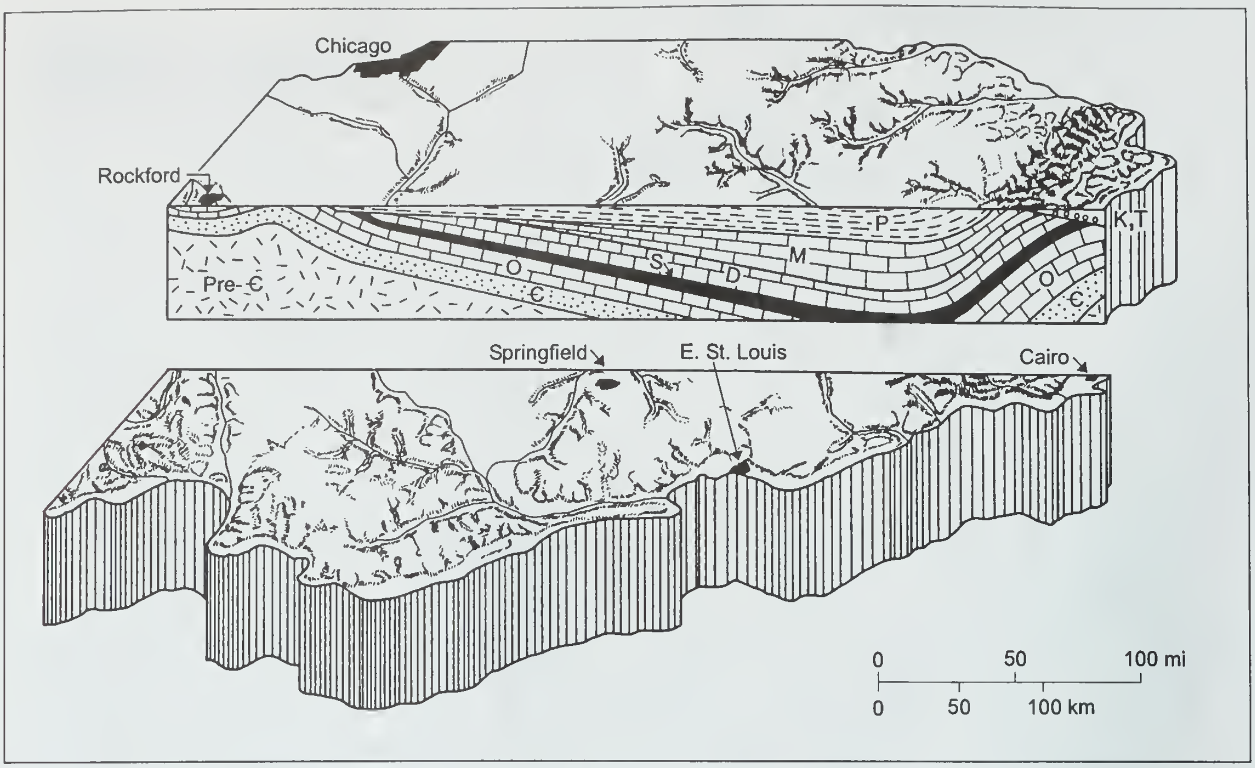


Figure 3 Stylized north–south cross section shows the structure of the Illinois Basin. To show detail, the thickness of the sedimentary rocks has been greatly exaggerated and younger, unconsolidated surface deposits have been eliminated. The oldest rocks are Precambrian (Pre-Є) granites. They form a depression filled with layers of sedimentary rocks of various ages: Cambrian (Є), Ordovician (O), Silurian (S), Devonian (D), Mississippian (M), Pennsylvanian (P), Cretaceous (K), and Tertiary (T). Scale is approximate.

overlying beds, the contact between the lower tilted beds and the overlying flat-lying rocks is called an angular unconformity.

Unconformities occur throughout the Paleozoic rock record and are shown in the generalized stratigraphic column (located in the front of this guidebook) as wavy lines. In figure 4, the unconformities are labeled with a "U." Each unconformity represents an extended interval of time for which there is no rock record in this area.

Silurian The oldest bedrock unit exposed at the surface in Rock Island County is the Silurian Racine Dolomite (fig. 4). We will examine the Racine Dolomite during the morning at the Collinson Brothers quarry in Milan, Illinois. Quarry operations have recently uncovered about 30 feet of the Racine. The unit ranges in color from light yellow brown to light brownish or greenish gray and is as thick as 300 feet.

The Racine Dolomite consists of numerous low oval reefs (bioherms) that vary in size from a few tens of feet to as much as ¼ mile in diameter (Hinman 1968). Larger reefs are present in northeastern Illinois and northern Indiana. An idealized Silurian reef is shown in figure 7. The reef core consists of a mass of porous and fractured dolomite. The numerous fossils that are typically present in the bioherm cores include corals, stromatoporoids, crinoids, brachiopods, and molluscs. Corals and stromatoporoids were the most abundant organisms. The coral *Favosites* is particularly abundant.

SYSTEM	SERIES	GROUP OR STAGE	SEQENCE	FORMATION	THICK-NESS	GENERAL DESCRIPTION
QUATER-NARY	Pleistocene	Illinoian			0-250'	Loess, till, silt, clay, sand, and gravel
						U
PENNSYL-VANIAN			Absaroka	Tradewater	0-200'	Alternating succession of sandstone shale, limestone, thin coal, and underclay
PENNSYL-VANIAN			Absaroka	Caseyville		
						U
DEVON-IAN			Kaskaskia	Cedar Valley	0-140'	Limestone
DEVON-IAN			Kaskaskia	Wapsipinicon	0-60'	Limestone
						U
SILURIAN	Niagaran		Tippecanoe	Racine	~300'	Dolomite
SILURIAN	Alexandrian		Tippecanoe	Marcus	40'	Dolomite
SILURIAN	Alexandrian		Tippecanoe	Sweeney	45-65'	Dolomite
	Alexandrian		Tippecanoe	Blanding	35-50'	Dolomite
ORDOVICIAN	Cincinnatian	Maquoketa	Tippecanoe		~240'	Shale, some dolomite
ORDOVICIAN	Champlainian	Galena	Tippecanoe		250'	Dolomite
ORDOVICIAN	Champlainian	Platteville	Tippecanoe		85-130'	Dolomite, slightly cherty; some limestone
ORDOVICIAN	Champlainian	Ancell	Tippecanoe	Glenwood	5'	Sandstone, silty
ORDOVICIAN	Champlainian	Ancell	Tippecanoe	St. Peter	70-160'	Sandstone
						U
ORDOVICIAN	Canadian	Prairie du Chien	Sauk	Shakopee	207'	Dolomite, some thin sandstone
ORDOVICIAN	Canadian	Prairie du Chien	Sauk	New Richmond	50'	Sandstone
ORDOVICIAN	Canadian	Prairie du Chien	Sauk	Oneota	~215'	Dolomite
CAMBRIAN	Croixan		Sauk	Eminence		Sandy dolomite
CAMBRIAN	Croixan		Sauk	Potosi	166'	Dolomite
CAMBRIAN	Croixan		Sauk	Franconia	180'	Sandstone, dolomite, shale
CAMBRIAN	Croixan		Sauk	Galesville	130'	Sandstone
CAMBRIAN	Croixan		Sauk	Eau Claire	300'	Sandstone, siltstone, shale
CAMBRIAN	Croixan		Sauk	Mt. Simon	1250'	Sandstone
PRECAMBRIAN						Granite

Figure 4 Generalized stratigraphic column for Rock Island County, Illinois (modified from Anderson,1980). Major unconformities are indicated by "U."

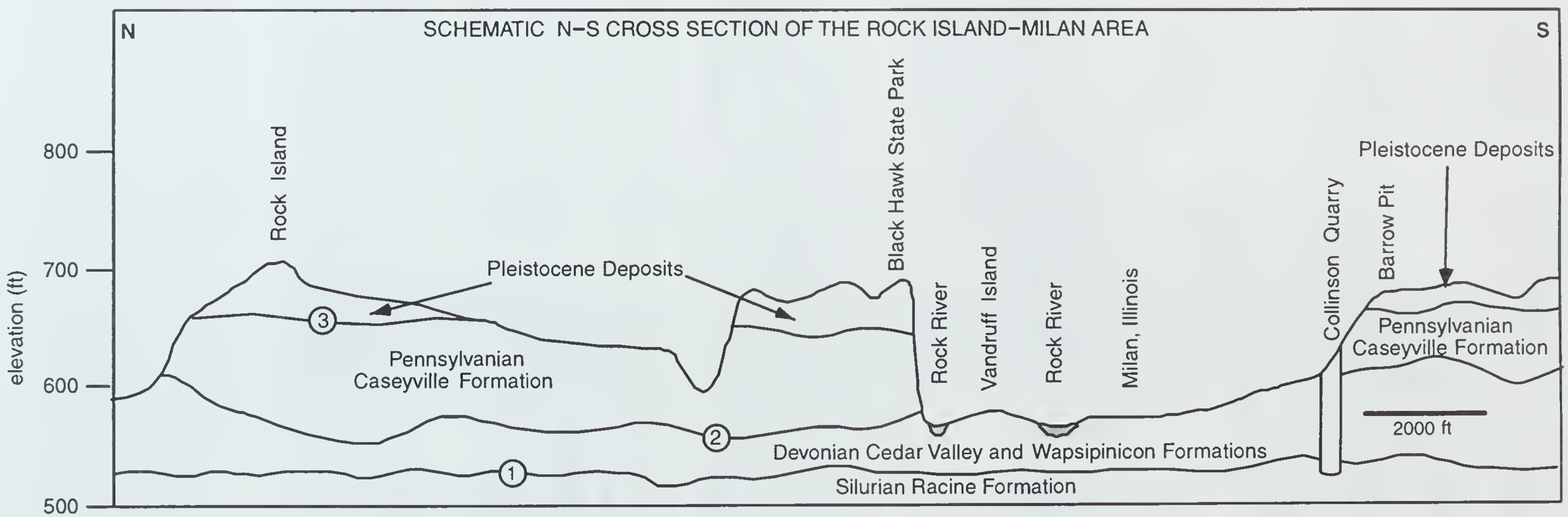


Figure 5 North–south topographic profile of the field trip area. Numbered lines mark the three major unconformities visible in the area.

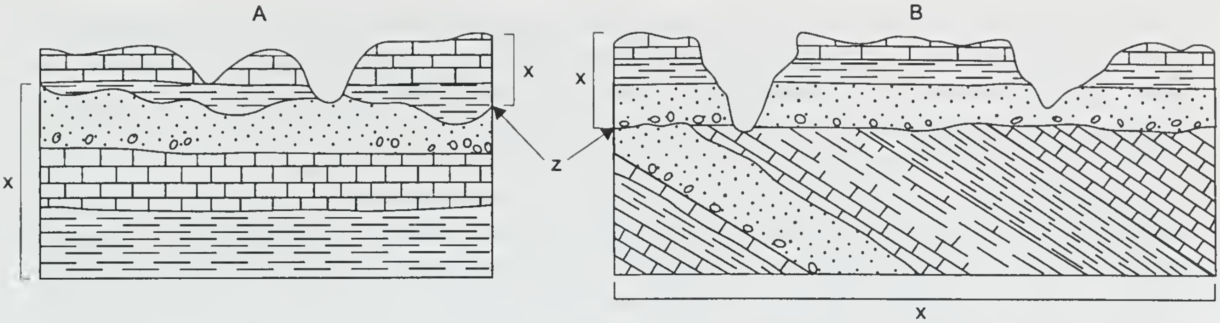


Figure 6 Schematic drawings of (A) a disconformity and (B) an angular unconformity (x represents the conformable rock sequence and z is the plane of unconformity).

The reef core is abutted by thinly to thickly bedded flank rocks that dip away from the core and merge with flat-lying inter-reef rocks on all sides. The flanks are less porous and less fractured than the core. Broken fossil debris is common here in the reef flank and inter-reef areas. Fossil preservation is typically poor in the Racine because of the extensive dolomitization that has altered the original composition of the rocks.

The Silurian reefs formed during a period when tropical shallow seas covered virtually all of what is now Illinois. During the Silurian, northern Illinois was located about 15° south of the paleoequator. Like modern coral reefs, the reefs grew in clear water at depths affected by the currents of ocean waves. Waves and currents caused debris broken from the reefs to be spread into the inter-reef areas.

Devonian In Rock Island County, Middle Silurian strata are unconformably overlain by strata of Middle Devonian age. In the center of the Illinois Basin, deposition was continuous from Late Silurian to Early Devonian time, but a major unconformity separates Early and Middle Devonian strata. This unconformity represents the boundary between the Tippecanoe and Kaskaskia Sequences (fig. 4). Available evidence in Rock Island County reveals little relief on this unconformity. Sinkholes and other solution features that would indicate weathering at the land surface are lacking, but the fossils clearly indicate that a major gap in the rock succession is present.

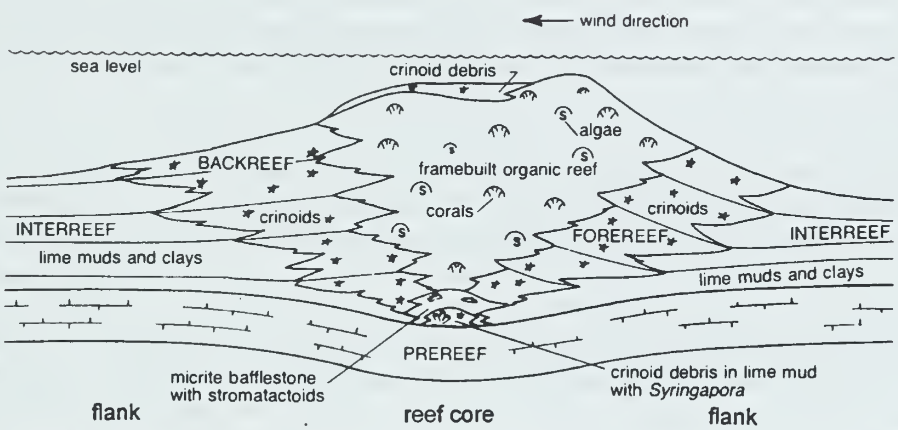


Figure 7 Idealized reef during Middle Silurian showing typical geometry of various facies composing buildup.

In the Quad Cities area, the Devonian consists of the Wapsipinicon and Cedar Valley formations (fig. 4). During Devonian time, the Quad Cities area lay on the eastern margin of the Central Iowa Basin, which at that time was separated from the Illinois Basin by the roughly east–west-trending Sangamon Arch in central Illinois (Collinson 1967) (see fig. 2).

Following the withdrawal of the seas at the end of Early Devonian time, the sea rapidly transgressed from the west and north and reached the Quad Cities area by Middle Devonian time, as recorded by deposition of the Wapsipinicon Limestone (fig. 4). The Wapsipinicon, which is as thick as 60 feet, gives abundant evidence for deposition in hypersaline conditions (conditions of highly increased salinity due to evaporation of seawater, which forms concentrated brines). Gypsum, a common evaporite rock (that is, a salt mineral formed by evaporation of seawater) that forms in hypersaline conditions, is widespread within the Wapsipinicon in southeastern Iowa. In the Rock Island area, where the Wapsipinicon is at the surface or is unconformably overlain by Pennsylvanian rocks, the formation is highly brecciated (broken into angular fragments), perhaps as the result of the dissolution of thick layers of gypsum and the collapse of the limestone layers into the empty spaces that formed. The Wapsipinicon also has very fine-grained layers with well-developed stromatolites, rip-up clasts, and scattered occurrences of mud cracks and dolomite; fossils are extremely rare. These characteristics are typical of limestones deposited under arid, shallow seas in tropical or subtropical latitudes, an environment similar to that of the modern Persian Gulf region. During the Devonian, what is now northern Illinois was located about 12° south of the paleoequator.

The Wapsipinicon Limestone is overlain by the Cedar Valley Limestone (fig. 4). In some places, there is evidence for a minor unconformity between the two units, but in other areas deposition was continuous. The Cedar Valley represents a transgressive onlapping succession of deposits that covered the Wapsipinicon when the seas reinvaded the area after a period of withdrawl. In the Rock Island area, the Cedar Valley consists of thickly to massively bedded, richly fossiliferous limestone that is as thick as 140 feet. Brachiopods are the dominant fossils, but crinoids, corals, bryzoans, cephalopods, trilobites, and rare shark teeth also occur. In places, the sediments were intensively burrowed by marine animals before they were lithified. The Cedar Valley limestone was deposited in a shallow marine environment with normal marine salinities. Erosion has removed much of the upper Cedar Valley Limestone in the Rock Island area.

Pennsylvanian In the Rock Island–Milan area, some Late Devonian strata and an unknown thickness of Mississippian strata were removed by erosion prior to Pennsylvanian time, so that in most places, Pennsylvanian strata rest directly upon the Cedar Valley Limestone. This unconformity marks the boundary between the Kaskaskia and Absaroka Sequences (see fig. 4). The unconformity surface reflects a well-developed karst landscape formed in an area of low to moderate relief (generally less than 200 feet).

Because of the occurrence of coal and the cyclic successions of strata, the Pennsylvanian rocks of the Illinois Basin have been extensively studied (see *Depositional History of Pennsylvanian Rocks in Illinois* at the back of this guidebook). Pennsylvanian strata consisting of shale, siltstone, sandstone, limestone, coal, and underclay were deposited as sediments in shallow seas, rivers, deltas, and swamps between about 320 and 288 million years ago. Rock Island County marks the northwesternmost extent of Pennsylvanian rocks in the Illinois Basin. Prior to the beginning of Pennyslvanian deposition, the Illinois Basin area was elevated at its north end and depressepd slightly at the south; the upturned edges of the strata were then beveled by erosion, forming an angular unconformity.

Two Pennsylvanian formations occur in the Rock Island area, the Caseyville and the Tradewater (see fig. 4), but only the Caseyville will be seen during this field trip. Prior to the deposition of the Caseyville Formation, the entire Illinois Basin area was above sea level, and a series of southwest-flowing streams incised valleys 200 to 300 feet below the adjacent upland plains. In areas where the surface rocks were limestone or dolomite, caves and sinkholes formed that were subsequently filled with Pennsylvanian sediments. The principal source area for Pennsylvanian sediments throughout much of the Illinois Basin was to the northeast in the Appalachian Mountains, but in the Quad Cities area, the sediments may have been derived from the north or northwest.

When the Lower Pennsylvanian seas advanced from the west, deposition of the Caseyville and Tradewater Formations was initially confined to the river valleys, which became brackish estuaries, bays, or lagoons as they were drowned by the rising sea. As a result, the oldest Pennsylvanian units in the area are discontinuous. The river valleys were eventually filled, and a level depositional surface was established. The Pennsylvanian strata in the field trip area are as thick as 200 feet.

The Caseyville Formation was initially believed to occur only in southern Illinois. O'Brien (1963) recognized the Caseyville Formation in the Quad Cities area on the basis of studies of fossil pollen in the coals. The Caseyville, which forms the bluffs overlooking the Rock River at Black Hawk State Historic Site, is the basal Pennsylvanian unit throughout much of central and southern Rock Island County. The Caseyville is dominated by thick sandstone units, composed of "clean" quartz sands that have little clay and only modest amounts of mica. These rocks are interpreted to have been deposited in fluvial or deltaic environments.

Although coals are common throughout the Pennsylvanian system in the Quad Cities area, only the Rock Island (No. 1) Coal of the Lower Tradewater Formation has been economically important. The Tradewater Formation overlies the Caseyville in part of the field trip area, but in the remainder of the region, it is the basal formation of the Pennsylvanian System. In the field trip area, the Tradewater is characterized by thin lenticular sandstones and limestones within thicker shale successions. Tradewater sandstones differ significantly from those in the underlying Caseyville. Tradewater sandstones generally are less clean and contain abundant rock fragments, especially mica and feldspar. The compositional and textural changes reflect a change in source materials.

Quaternary System No rocks of Permian, Mesozoic, or Tertiary age occur in the Quad Cities area. The present course of the Mississippi River below the Quad Cities and its deeply incised valley date to the Pleistocene. Prior to the establishment of the present course of the Mississippi River at the Quad Cities in late Pleistocene time, the course of the river in western Illinois, below Muscatine, Iowa, was occupied by a river whose headwaters lay in the drainage basins of the present Cedar and Iowa Rivers in east-central Iowa. Thus, although the present course of the Mississippi River in western Illinois bears a close relationship to the western margin of Illinoian glacial deposits and appears to have been determined by the Illinoian glaciers, a valley almost certainly existed in that location prior to Illinoian glaciation and probably in preglacial time as well. The Pleistocene glaciations and their effects on preglacial drainage patterns are summarized in *Pleistocene Glaciations in Illinois* at the back of this guidebook.

Between Cordova, Illinois, and Muscatine, Iowa, the Mississippi River flows across a preglacial drainage divide. This course is a result of diversions of the southeastward-flowing Ancestral Mississippi River by Illinoian and later Wisconsinan ice moving south and west across Illinois from the Lake Michigan basin. These diversions caused proglacial lakes to form when the river was blocked by the glacial ice. The level of these lakes rose until the water flowed over the lowest point within the

lake's basin. The most significant breach of these former divides in the Quad Cities area is located at Wyoming Hill, Iowa. The development of this outlet established the present course of the Mississippi River in the Quad Cities area. Lacustrine sediments associated with these proglacial lakes will be examined at Stop 1.

The Quaternary stratigraphy in this area is primarily Illinoian till (the Kellerville Till member of the Glassford Formation) with a well-developed Sangamon Soil in its upper portions, overlain by the Peoria Loess of Wisconsinan age. Lacustrine sediments occur between the till and the loess. In places, pre-Illinoian tills have been recognized. Modern alluvium occurs within the main channel and floodplains of the Mississippi and Rock Rivers.

GUIDE TO THE ROUTE

We'll start the trip in the parking lot of the South Park Mall, Moline. Assemble in the northwest corner of the parking lot next to Montgomery Wards and the outer mall road. The mall is located in the SE quarter of the NW quarter of the NW quarter of Sec. 16, T17N, R1W, 4th PM, Milan 7.5-Minute Quadrangle. Mileage will start at the northeast entrance/exit of South Park Mall.

You must travel in the caravan. Please drive with headlights on while in the caravan. Drive safely but stay as close as you can to the car in front of you. Please obey all traffic signs. If the road crossing is protected by an Illinois State Geological Survey (ISGS) vehicle with flashing lights and flags, please obey the signals of the ISGS staff directing traffic. When we stop, park as close as possible to the car in front of you and turn off your lights.

Private property Some stops on the field trip are on private property. The owners have graciously given us permission to visit on the day of the field trip only. Please conduct yourselves as guests and obey all instructions from the trip leaders. So that we may be welcome to return on future field trips, follow these simple rules of courtesy:

- Do not litter the area.
- Do not climb on fences.
- Leave all gates as you found them.
- Treat *public* property as if you were the owner—which you are!
- Stay off of all mining equipment.
- Parents must closely supervise their children at all times.

When using this booklet for another field trip with your students, a youth group, or family, remember that *you must get permission from property owners or their agents before entering private property.* No trespassing please.

Two USGS 7.5-Minute Quadrangle maps (Coal Valley and Milan) provide coverage for this field trip area.

Miles to next point	Miles from start	
0.0	0.0	**South Park Mall** is built on 5 to 10 feet of fill. Before the mall was constructed, the elevation at the top of the banks along Rock River was at 560 feet and the natural floodplain north of Rock River extended ¾ mile to the 570-foot contour line. This low area, where the mall now stands, was a swamp. Presently, the 570-foot contour line is at the south end of the mall, and the floodplain has been reduced to less than ¼ mile wide. Before the mall was constructed, the creek at the west side of the mall drained into the swamp not the river. Now the creek is channelized all the way to the river.
		TURN RIGHT (south) onto 27th Street. Set your mileage to 0.0 at the northeast exit/entrance of South Park Mall.
		Note the drainage way between the road and the mall parking lot. Prior to mall construction, this drainage way was located on the other side of the road.

0.2	0.2	Stoplight (intersection of East Mall Entrance). CONTINUE SOUTH.
0.2	0.4	Stoplight (intersection of 52nd Avenue and 27th Street). CONTINUE SOUTH.
0.1	0.5	North abutment of bridge over Rock River.
0.1	0.6	South abutment of bridge.
0.2	0.8	Bridge over Interstate 280/74. The low hill ahead is a remnant of a terrace that marked a former floodplain of the river. The terrace is underlain by a resistant bedrock island.
0.1	0.9	Stoplight (intersection of Airport Road and 27th Street). CONTINUE AHEAD. Directly ahead to the south are the bluffs that form the valley of the Rock River.
0.1	1.0	Road begins a large, gentle 90° curve to the left.
0.3	1.3	Stoplight. T-intersection from the left (Route 6 and access to I-74/280). CONTINUE AHEAD (east). We are now following Route 6 East, which is also West First Avenue
0.5	1.8	Stoplight. T-intersection from the right (Route 150). CONTINUE EAST on Route 6. Right lane ends. MERGE LEFT.
0.2	2.0	Bridge over Coal Creek. The creek has been channelized and its mouth relocated ¼ mile downstream.
0.3	2.3	Enter Coal Valley, population 3,500, established in 1856. Coal Valley and Coal Creek are named after the 3- to 6-foot-thick exposures of the Rock Island Coal. This coal was mined in the area for several years near Coal Valley and Carbon Cliff. The Rock Island Coal is generally overlain by the very dark gray to black Seville Limestone. The Seville Limestone is generally thickest over the thickest coal.
0.75	3.05	T-intersection from the right (First Street). TURN RIGHT (south) onto First Street.
0.25	3.3	Crossroad intersection (East 4th Avenue and West 4th Avenue, and 1st Street). TURN RIGHT (west) onto West 4th Avenue. PROCEED WITH CAUTION: The road surface is rough. One of the first things to notice (to the left) as you follow this road is the large number of trees whose trunks are bent near their bases. These bent tree trunks are strong indications that the soil in the bluffs is unstable and that slumping has occurred. Bent tree trunks are a feature commonly found when the earth is sliding downhill. To your right is the large Rock River floodplain.
0.9	4.2	Begin crushed-rock road surface; the road is now 78th Avenue.

0.2	4.4	Pull over to the far right side of the road. Watch out for traffic and use caution when exiting vehicles.

STOP 1 Borrow Pit of C. E. Peterson and Sons

0.0	4.4	Leave Stop 1 and CONTINUE AHEAD.
0.1	4.5	Crossing Coal Creek. The Rock Island Coal and the Seville Limestone are exposed about 2 miles upstream.
0.1	4.6	Stop (2-way). Intersection of Route 150. CONTINUE WEST on 78th Avenue (Note: this is also Rock Island County Road JJ). CAUTION: Fast-moving traffic from the right and left.
0.4	5.0	Dissected loess and till on the left with evidence of creep and slump.
0.7	5.7	Crossing small unnamed creek. Outcrop of Seville Limestone over Rock Island Coal occurs about 2,000 feet upstream to the south. At present, the route is on a valley wall terrace.
0.3	6.0	T-intersection from the right. Access road to Indian Bluff Forest Preserve and public golf course. CONTINUE AHEAD. The valley wall consists of the unconsolidated materials also present at Stop 1. There is nothing strong to hold up the hillside, and slumping occurs for the next mile.
1.0	7.0	Crossing Case Creek. Case Creek has been channelized from the road to the river. The west abutment of the bridge is the tie point for an artificial levee to protect Milan between Case Creek and Mill Creek. During the early spring of 1965, heavy rains caused flash flooding, and Case Creek shifted about 100 feet as saturated shale, mudstone, and coal, along with till and loess, slumped into the creek downstream from a low knob of Cedar Valley Limestone. Upstream, the creek cut laterally into an alluvial terrace to triple the width of its floodplain.
0.6	7.6	Stop (4-way). Intersection of Milan Beltway. CONTINUE AHEAD (west). The road becomes 10th Avenue.
0.6	8.2	Stoplight. T-intersection from the left (Knoxville Road). CONTINUE WEST on 10th Avenue.
0.15	8.35	Crossing Mill Creek. The United States Geological Survey stream gauging station is on the left. Historic streamflow data beginning with 1936 and real-time streamflow data are available from the United States Geological Survey online at http://waterdata.usgs.gov/nwis-w/IL/?statnum-05448000 Notice the levees on both sides of the creek to your right.

0.25	8.6	T-intersection from the left. Entrance to Collinson Brothers, Milan Quarry. TURN LEFT. Follow the lead vehicle into the quarry, and assemble for safety instructions and the geology presentation.

STOP 2 Collinson Brothers, Milan Quarry

0.0	8.6	Leave Stop 2. Follow the quarry road back to 10th Avenue and TURN LEFT.
0.15	8.75	Stoplight. Entrance to Eagle Distribution Center to the right. CONTINUE WEST on 10th Avenue.
0.25	9.0	Stoplight (intersection of Route 67). CONTINUE WEST on 10th Avenue.
0.25	9.25	Stoplight (intersection of 4th Street West). CONTINUE WEST (10th Avenue is now on Andalusa Road).
0.35	9.6	Crossing unnamed creek.
0.1	9.7	CAUTION: Cross single set of railroad tracks. Single lights, no guard gates.
0.25	9.95	Crossing Kyte Creek.
0.05	10.0	Stoplight. T-intersection from the left (Ridgewood Road). CONTINUE WEST on Andalusa Road (also named 78th Avenue). Entering Rock Island, population 40,600.
0.6	10.6	To your right is an abandoned sand and gravel pit, now the Camelot Camp Ground.
1.25	11.85	Stoplight. Crossroad intersection (Route 92 East and Andalusia Road). TURN RIGHT. Follow signs indicating Rock Island–Davenport at the intersection. After you make your turn, you're heading north on Route 92 (Centennial Expressway).
0.3	12.15	Wastewater treatment facility on the right (north).
0.1	12.25	Crossing Mill Creek. This is not the same creek that had the gauging station at Stop 2 but a creek that drains Kickapoo Slough. This creek may have been a distributary on the fan-delta of the Rock River. Note the wooded wetlands on both sides of the road.
0.45	12.7	T-intersection from the right. TURN RIGHT. Entrance to Moline Consumers, General Sand and Gravel Pit. Follow the lead vehicle into the sand and gravel operations, and assemble for safety instructions and the geology presentation.

STOP 3 Moline Consumers, General Sand and Gravel Pit

0.0	12.7	Leave Stop 3. Retrace the route back to Route 92 and TURN RIGHT. CAUTION: Fast-moving traffic from your left. Note: This is a divided highway.
0.1	12.8	Entrance ramp to I-280 East. CONTINUE NORTH on Route 92 (Centennial Expressway).
0.3	13.1	Center of bridge over I-280.
0.1	13.2	Entrance ramp to I-280 West. CONTINUE NORTH on Route 92 (Centennial Expressway).
0.8	14.0	Crossing Hennepin Canal. This section of the Hennepin Canal is about 3 miles long. It was constructed to bypass the low head pool formed by construction of the Sears Hydroelectric Power Plant. The pool was formed by construction of two dams: the dam adjacent to the power plant, and Steel Dam at the east end of Vandruff Island. This segment of the canal, between locks 30 and 32, was completed in 1907 and was only 7 feet deep. It was abandoned in 1935.
0.1	14.1	Crossing Rock River. Turkey Island is to the right. Prepare to exit onto 31st Avenue in Rock Island.
0.2	14.3	MERGE RIGHT onto exit ramp to 31st Avenue.
0.1	14.4	Stop (1-way). TURN LEFT (west) onto 31st Avenue and pass under Route 92.
0.2	14.6	Entrance to Sunset Park. Note: As soon as you enter the park, bear to the right onto Sunset Lane. The marina is to your left.
0.3	14.9	Picnic shelter at Sunset Park. Pull over to the right side of the road.

STOP 4 Lunch and discussion of Mississippi River history

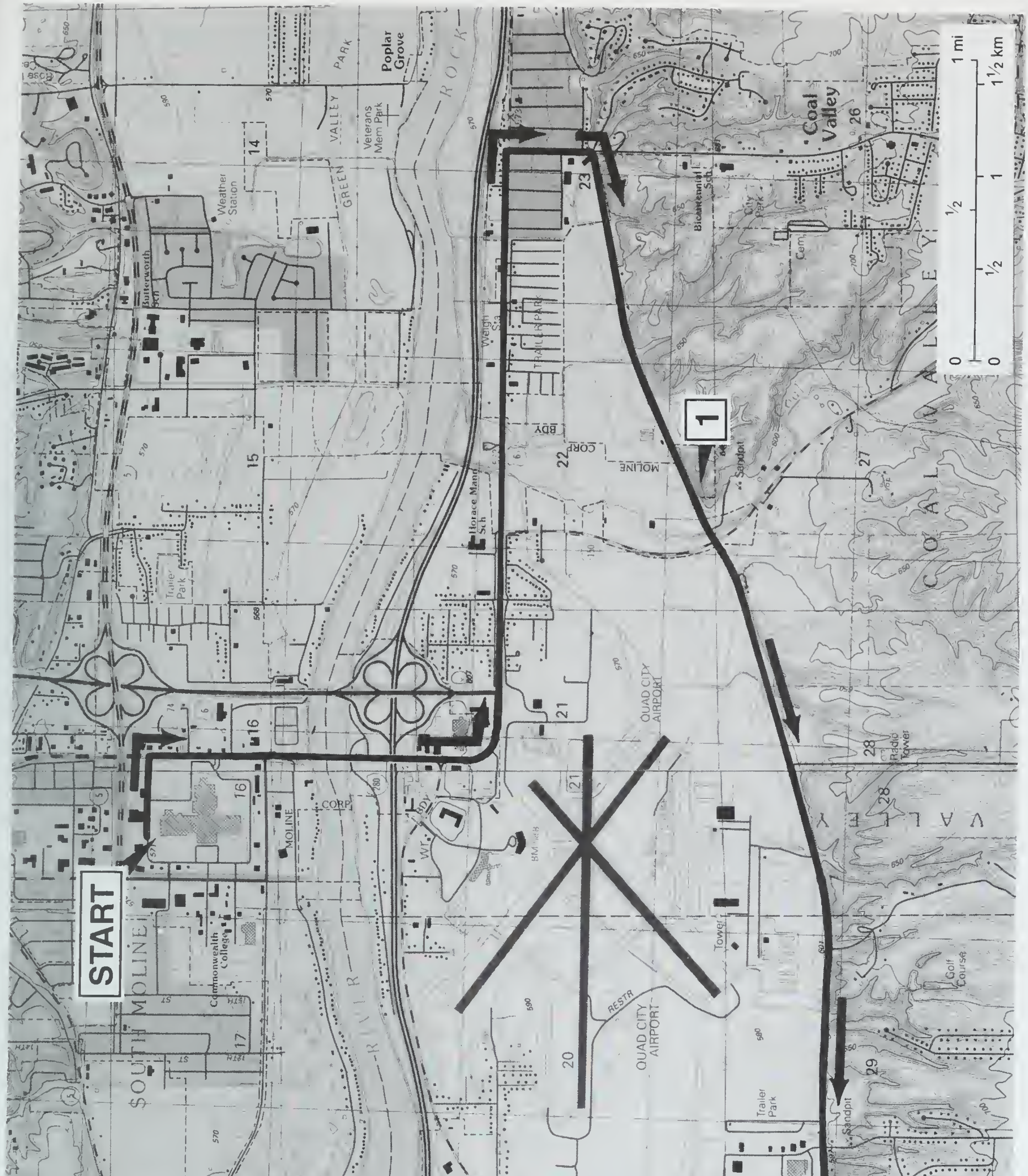
0.0	14.9	Leave Stop 4 and CONTINUE AHEAD.
0.4	15.3	T-intersection (Sunset Lane and 18th Avenue). TURN RIGHT (east) and exit Sunset Park onto 18th Avenue.

During the major 1965 flood on the Mississippi River, earthen dikes were constructed to protect the industrial area to the north of 18th Avenue. One set of dikes was built along the river's edge and joined to 18th Avenue. A second dike was constructed along the south side of 18th Avenue. About 3 days before the expected crest, the dike along the river failed at the Rock Island Boat Club, and the industrial area north of 18th Avenue flooded to the railroad embankment.

		After the flood, the city began constructing a permanent levee. This levee was strengthened and raised during the floods of 1975 and 1993.
0.3	15.6	CAUTION: Crossing single railroad track. Lights, no guard gate. This was the fallback position during the 1965 flood. Filled sandbags were loaded on railroad flat cars and brought here for construction of a sandbag dike.
0.1	15.7	Crossing under Route 92 (Centennial Expressway).
0.1	15.8	Ascending Savanna Terrace. This is a major terrace along the Mississippi River.
0.3	16.1	Stop (4-way). Intersection with 9th Street (Martin Luther Drive). CONTINUE EAST.
0.15	16.25	Stoplight. TURN RIGHT (south) onto 11th Street (U.S. 67).
0.55	16.8	Stoplight (25th Avenue). CONTINUE SOUTH.
0.4	17.2	Stoplight (31st Avenue). CONTINUE SOUTH.
0.5	17.7	Silhouette statue of Black Hawk to the right.
0.15	17.85	Stoplight (42nd Avenue). Prepare to merge to the left lane just after the stop-light. Sign: Black Hawk State Historic Site and Museum.
0.25	18.1	Stoplight (intersection of U.S. Route 67 and Illinois Route 5). TURN LEFT onto Route 5 (Black Hawk Road) to Black Hawk State Historic Site. Note: This is also 46th Avenue.
0.25	18.35	The road now ascends an old creek cut; loess is exposed on both sides of the road.
0.05	18.4	TURN LEFT onto 15th Street. We will spend the rest of the afternoon in the Black Hawk State Historic Site. We will use two parking lots on the day of the field trip.
0.1	18.5	Entrance to the lower parking lot is to your right, just before 45th Avenue. Pull into the parking lot and park as you normally would. The second parking lot is located at the end of 15th Street. Follow the detailed trail map provided in the guidebook while traveling in the park. After cars are parked, everyone should walk and meet at the lower parking lot near the A-frame shelter house.

STOP 5 Black Hawk State Historic Site

End of road log.


START
1
SOUTH MOLINE
Commonwealth College
QUAD CITY AIRPORT
Tower
RESTR
Coal Valley
Poplar Grove
Veterans Mem Park
GREEN VALLEY PARK
Weather Station
Butterworth Sch
Horace Mann Sch
Trailer Park
TRAILER PARK
Weigh Sta
Bicentennial Sch
City Park
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Golf Course
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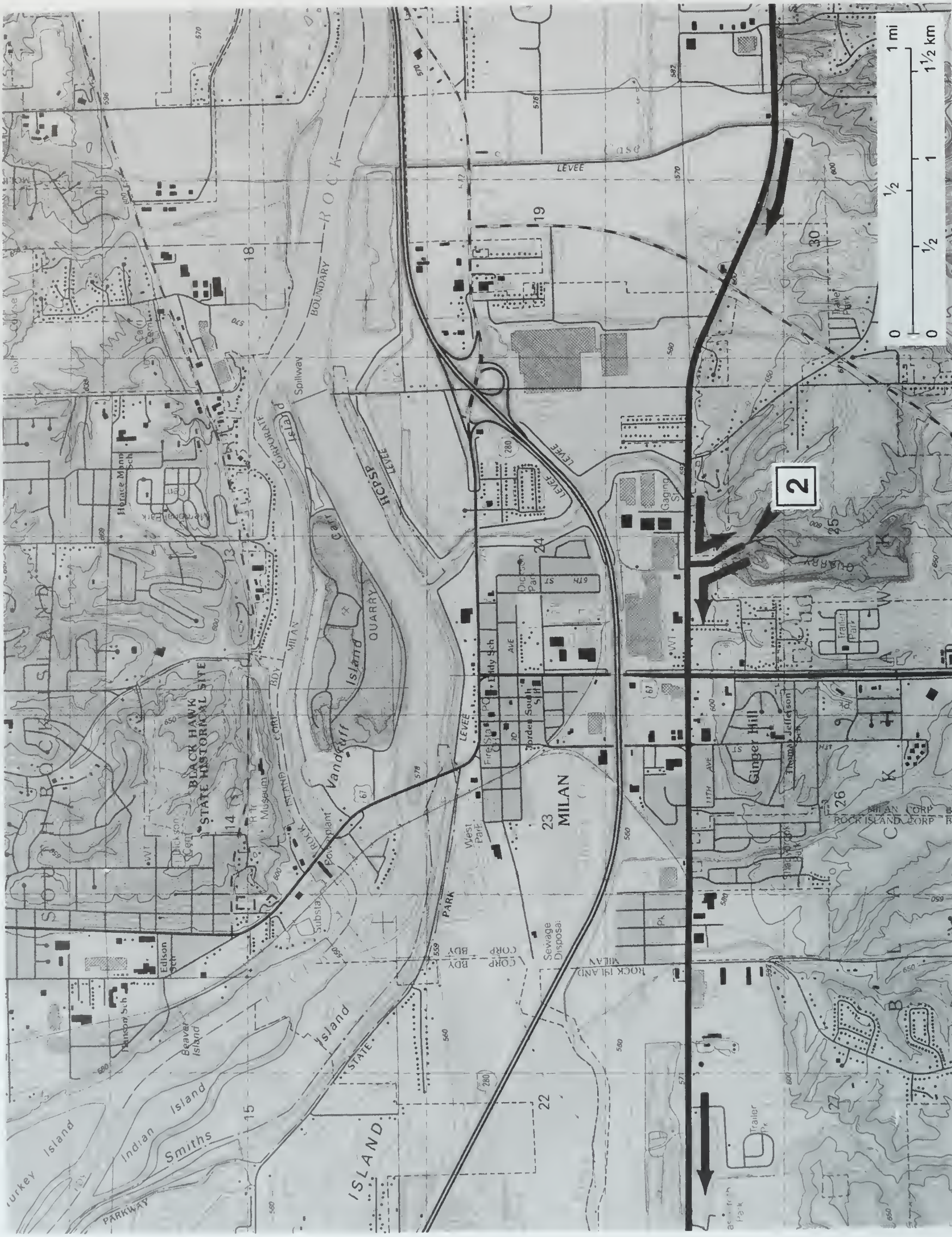
MILAN
BLACK HAWK STATE HISTORICAL SITE
ROCK
ISLAND
Vandruff Island
QUARRY
Ginger Hill
LEVEE
Spillway
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Case
Horace Mann Sch
Thomas Jefferson Sch
Edison Sch
Museum
West Park
Sewage Disposal
Trailer Park
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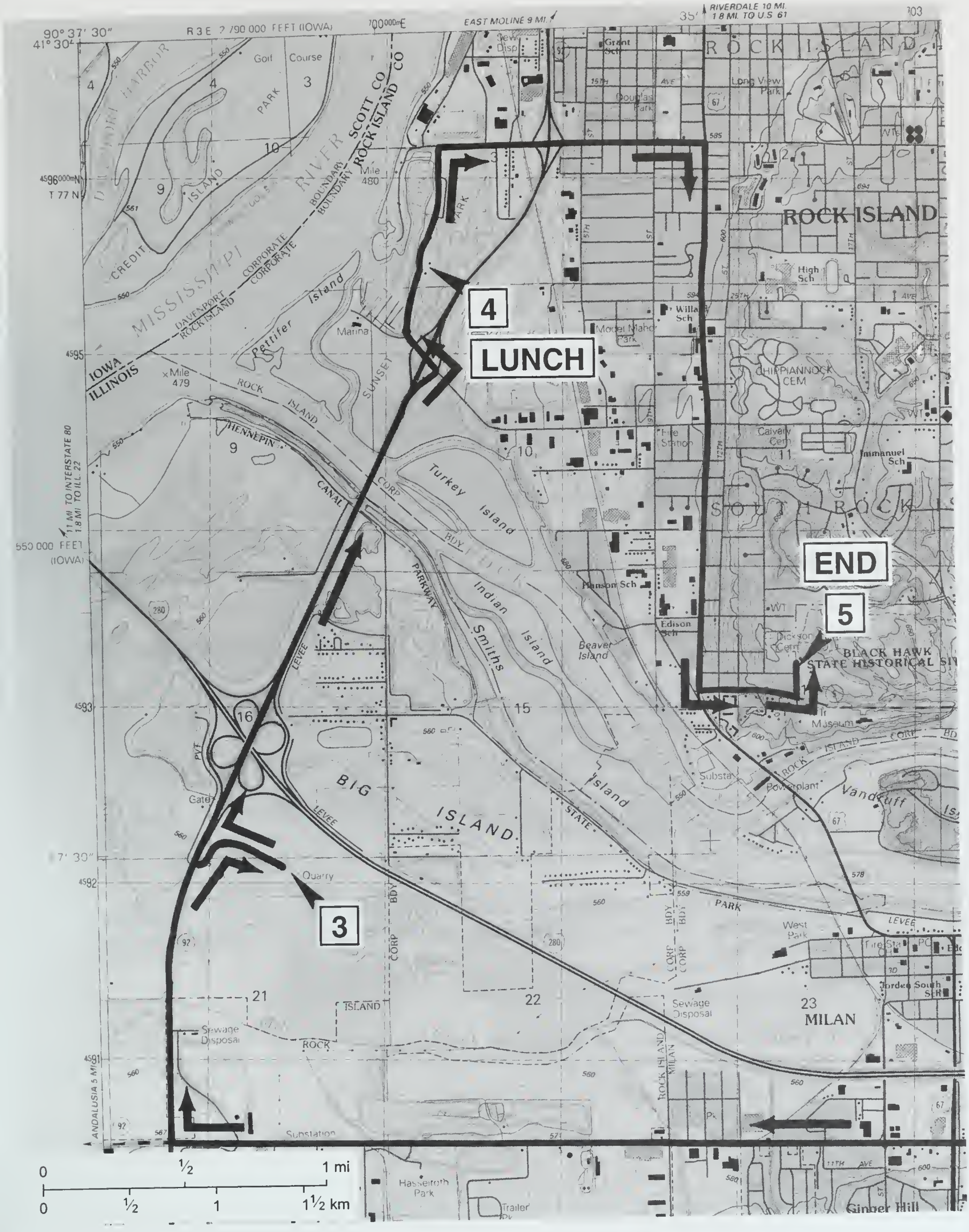
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SCOTT CO
ROCK ISLAND CO
BOUNDARY
DAVENPORT
ROCK ISLAND
CORPORATE
IOWA
ILLINOIS
Mile 480
Mile 479
Pettifer Island
Marina
SUNSET
4
LUNCH
Model Mahon Park
Grant Sch
Douglas Park
Long View Park
High Sch
Willard Sch
CHIPPIANNOCK CEM
Calvary Cem
Immanuel Sch
Fire Station
SOUTH ROCK
END
5
Hanson Sch
Edison Sch
Dickson Cem
BLACK HAWK STATE HISTORICAL SITE
Museum
ROCK ISLAND
HENNEPIN
CANAL
Turkey Island
Indian Island
Smiths Island
Beaver Island
PARKWAY
LEVEE
BIG ISLAND
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3
Gate
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STOP DESCRIPTIONS

STOP 1 Borrow Pit of C. E. Peterson and Sons (NW NE,Sec. 27, T17N, R1W, 4th PM, Coal Valley 7.5-Minute Quadrangle, Rock Island County). This is the "Coal Creek Section" (fig. 8).

The Coal Creek Section displays many of the Pleistocene units found in the Quad Cities area: Peoria Loess overlying laminated silt and fine sand that represents Glacial Lake Milan (Equality Formation), which in turn rests on thin Roxana Silt overlying the Sangamon Soil. Near the base of the section, the Kellerville Till(s) occur. The results of clay mineral, particle size, and carbonate analysis on five samples of these tills indicate that these are typical Kellerville Tills: silty, illitic (containing micaeous clay minerals), with a calcite–dolomite ratio of less than 0.2. Ostracods collected from the Equality Formation indicate that Glacial Lake Milan was a body of standing water about 20 feet deep, probably surrounded by a mixed coniferous-hardwood forest. Mean annual temperature was probably around 40°F and annual precipitation was between 16 and 38 inches. In contrast, the modern mean annual temperature is 49.6°F, and the mean annual precipitation is 39.08 inches. Whereas in most places in the Quad Cities area the Sangamon Soil is developed on the Kellerville Till, here it is developed on the Teneriffe Silt.

The sequence of events recorded by this section is, briefly, as follows:

1. Deposition of one or more Illinoian Tills (Kellerville), intimately associated with glacio-fluvial and glacio-lacustrine sand and gravel during the Liman Substage (see *Pleistocene Glaciations in Illinois* at the back of this guidebook).

2. Retreat of the Illinoian glacier and deposition of the Teneriffe Silt in proglacial lacustrine and aeolian environments.

3. Formation of the Sangamon Soil during the Sangamonian Interglacial Age.

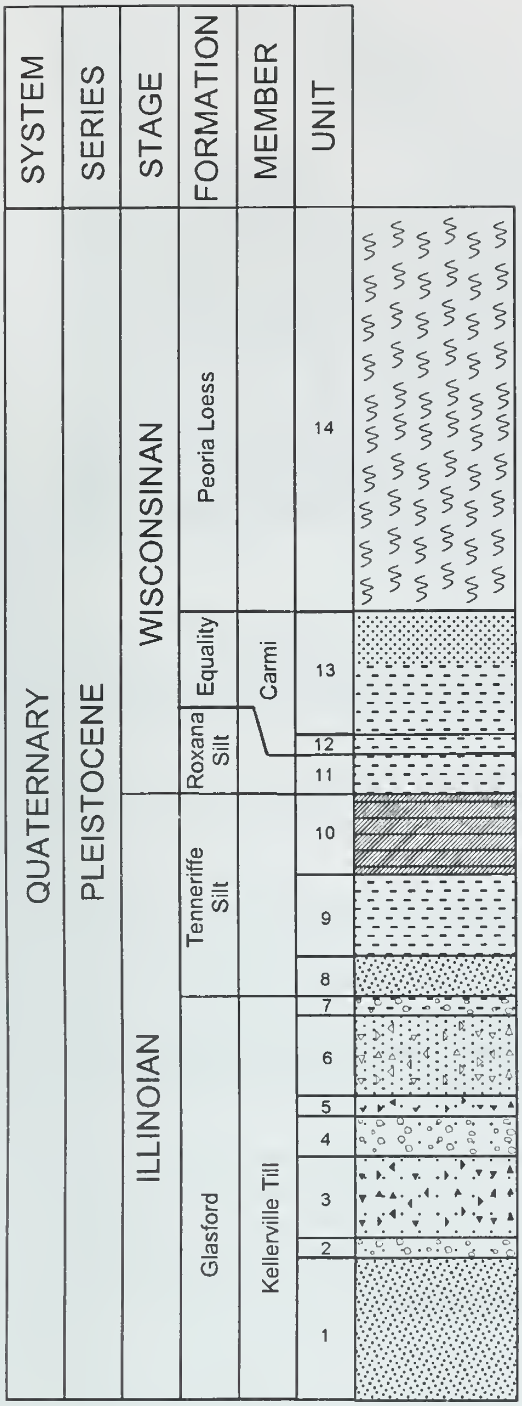
4. Deposition of the aeolian Roxana Silt during Altonian time.

5. Advance of the Middle Wisconsinan (Woodfordian glacier) into the Green River Lowland, blocking the southeastward course of the Ancestral Mississippi River, forming Glacial Lake Milan, and resulting in deposition of the Carmi Member of the Equality Formation.

6. Draining of Glacial Lake Milan as the present course of the Mississippi River was established past the Quad Cities, and deposition of the Peoria Loess, derived in large part from the former lake plain.

Things to look for at this site include:

1. The subtle differences between the till, silt, and clay units.
2. The intimate association of till, sand, and gravel.
3. Features that indicate a lacustrine environment.
4. The Sangamon Soil.
5. Gastropods in the Peoria Loess.



14. Silt, yellowish-brown, calcareous, contact between No. 13 and No. 14 covered, truncated at top. Thickness = 20 feet.

13. Silt and very fine sand, calcareous, faint regular laminations, light yellow brown, laminations are more obvious and the sediment is coarser near the top. Thickness = >6 feet.

12. Silt, interbedded light gray and light yellow brown. Crude color banding, calcareous, ostracods. Thickness = 1 foot.

11. Silt, dark gray-brown. Thickness = 2 feet.

10. Clay, silty, scattered pebbles, leached, well developed blocky structure. Light gray at base grading upward into dark gray. Iron oxide pellets. thickness = 4 feet.

9. Silt, light gray, massive to laminated. Some drop stones near the base. Thickness = 4 feet

8. Sand, medium to coarse, pebbly, leached at the top. Thickness = 1 foot.

7. Gravel, sandy, silty. Thickness = 1 foot.

6. Till, brownish-yellow, calcareous, scattered lenses of gravel. Thickness = 4 feet.

5. Till, gray, same as unit No. 3. Thickness = 1 foot.

4. Gravel, sandy, lenticular. Thickness = 0–2 feet.

3. Till, dark gray, calcareous. Thickness = 4 feet.

2. Gravel, sandy, silty, (washed till). Thickness = 0.5–1 foot.

1. Sand, fine to medium, poorly bedded to massive, some grains of coal, yellow to yellow brown, base concealed. Thickness = 7 feet.

Figure 8 Stratigraphic column for Stop 1, Coal Creek Section (modified from Anderson and others 1982).

STOP 2 Collinson Brothers, Milan Quarry (east half of the NW and SW quarter of Sec. 25, T17N, R2W, 4th PM, Milan 7.5-Minute Quadrangle, Rock Island County) (fig. 9).

Because it exposes the most complete section of Devonian rocks in northwestern Illinois and because it has been studied repeatedly over many years, the Collinson Quarry has become an important Devonian reference section (fig. 10). The upper Racine Formation (Silurian), the Wapsipinicon Limestone, and the lower two members of the Cedar Valley Limestone (Middle Devonian) are all well exposed, as are Pennsylvanian caves (paleo-karst or ancient karst) fillings.

Things to look for at this site include:

1. Large-scale brecciation in the Kenwood and Spring Grove Members of the Wapsipinicon affecting a vertical section of 10 feet or more and having clasts as much as 3 feet in maxi mum dimension.

2. Small-scale brecciation in the Davenport Member of the Wapsipinicon confined to individual beds generally less than 1 foot thick with clasts less than 2 inches indiameter.

3. Stylolites (solution zones).

4. Minor faults and flexures, probably resulting from dissolution of limestone.

5. Caves or sinkholes filled with Pennsylvanian shales and sands.

6. Stromatolites (algal fossils).

7. Contrast between the Wapsipinicon and the overlying Cedar Valley Limestones.

8. Invertebrate fossils in the Rapid Member of the Cedar Valley Formation (see *Devonian Fossils of Northwestern Illinois* at the back of this guidebook).

9. Trace fossils.

10. The Silurian–Devonian unconformity.

11. The lithologic characterisitics of the Racine Dolomite (Silurian).

Stop 3 Moline Consumers, General Sand and Gravel Pit (NE, Sec. 21, T17N, R2W, 4th PM, Milan 7.5-Minute Quadrangle, Rock Island County) (fig. 11)

This dredge operation is located near the center of a reworked fan-shaped deltaic sand and gravel deposit. Outbursts of meltwater transported sand and gravel down the newly positioned Mississippi River. Once the torrents cleared the Rock Island Rapids, the sand and gravel was deposited against the east valley wall and into the mouth of the Rock River as the Savanna Terrace (elevation 580 feet). Later, during outbursts down the Rock River, a portion of the terrace was washed away and

Figure 9 Collinson Brothers, Milan Quarry – Pennsylvanian Caseyville channel sandstone cutting into the underlying Cedar Valley Limestone. The contact between the sandstone and the limestone is an unconformity (photo by W. Frankie).

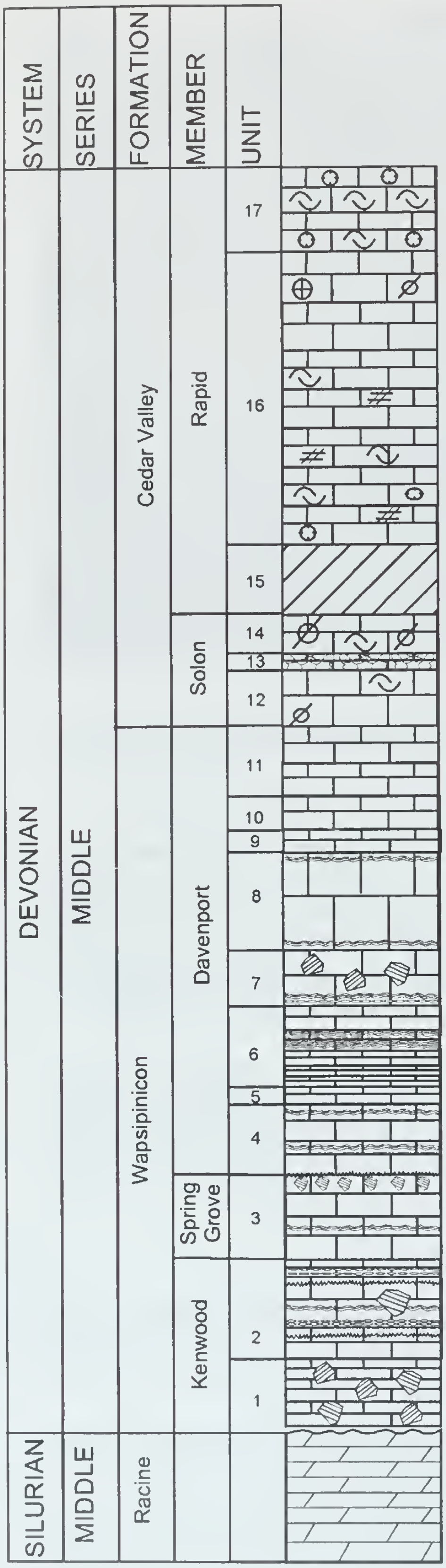
reworked to the present 560-foot level. Resistant knobs of Cedar Valley Limestone at Stop 2 and Stop 5 constricted the Rock River much like a nozzle on a hose. The valley floor between Stops 2 and 5 is slightly less than half the width of the valley floor where we crossed the river on the way to Stop 1 (see Route Map). One of the indicators of the source of gravel in the Savanna Terrace is the presence in the gravel of Lake Superior agate. With some luck you should fine some agates in the gravels at the approved collecting location.

In a dredge operation, an auger raises the sand and gravel from the lake floor and pumps it into a pipeline to the plant. At the plant, the materials are sorted by size and stockpiled. Sand is generally rejected and sent back to the lake or piled for contouring during reclamation. The 1974 Mining Act requires reclamation during and after mining. Thus, an important part of developing a mine, quarry, or gravel pit is planning how to reclaim it.

STOP 4 Lunch: Sunset Park (SW, Sec. 3, T17N, R2W, 4th PM, Milan 7.5-Minute Quadrangle, Rock Island County) Are You Hungry?

After lunch, we will discuss the history of the Mississippi River and the attempts to maintain navigation. This discussion will be held at the river observation platform at the north end of the park.

The Rock Island Sand and Gravel Company operated a gravel pit at this site for a number of years prior to World War II. The operation was probably very similar to that of the General Sand and



17. Limestone (wackestone), numerous brchiopods and crinoids, beds 1" to 6' thick, grayish yellow. Thickness = 6.5 feet.

16. Limestone (wackestone), massive, light gray, interbedded with highly fossiliferous light gray, thin bedded wackestone. Abundant brachiopods, horn corals, bryozoans, and burrows. Thickness = 26 feet.

15. Covered interval. Thickness = 5.5 feet.

14. Limestone (mudstone), numerous corals and brachiopods, grayish-yellow, top forms upper quarry bench. Thickness = 3 feet.

13. Limestone (mudstone), burrowed, yellowish-gray with lighter brown mottlings (burrows), scattered brachiopods. Thickness = 1 foot.

12. Limestone (mudstone), scattered horn corals and brachiopds, light gray. Thickness = 4 feet.

11. Limestone (mudstone), very fine grained, very light gray. Thickness = 5 feet.

10. Limestone (mudstone), very fine grained, light olive gray. Thickness = 3 feet.

9. Limestone (mudstone), very fine grained, massive yellowish gray, lenticular. Thickness = 1 foot.

8. Limestone (mudstone), very fine grained, massive, stromatolites at base and top. Thickness = 7 feet.

7. Limestone (mudstone), massive, brecciated, light gray, stromatolites and intraclasts, light gray. Thickness = 4 feet.

6. Limestone (mudstone), pale yellowish brown, stromatolites. Thickness = 5.5 feet.

5. Limestone (mudstone), pinkish gray, subtle laminations. Thickness = 1 foot.

4. Limestone (mudstone), light olive gray, stromatolites, solution contact with lower unit. Thickness = 5.5 feet.

3. Limestone (mudstone), massive, stromatolites, breccia. Thickness = 6 feet.

2. Limestone (mudstone), stromatolites, pyrite, stylolites, intraclasts, highly brecciated. Thickness = 7 feet.

1. Limestone (mudstone), stromatolites, pyrite, yellowish-brown, highly brecciated. Thickness = >5 feet.

UNCONFORMITY

Dolomite, light yellow-brown. Base concealed.

Figure 10 Stratigraphic column for Stop 2, Collinson Brothers, Milan Quarry (modified from Anderson and others 1982).

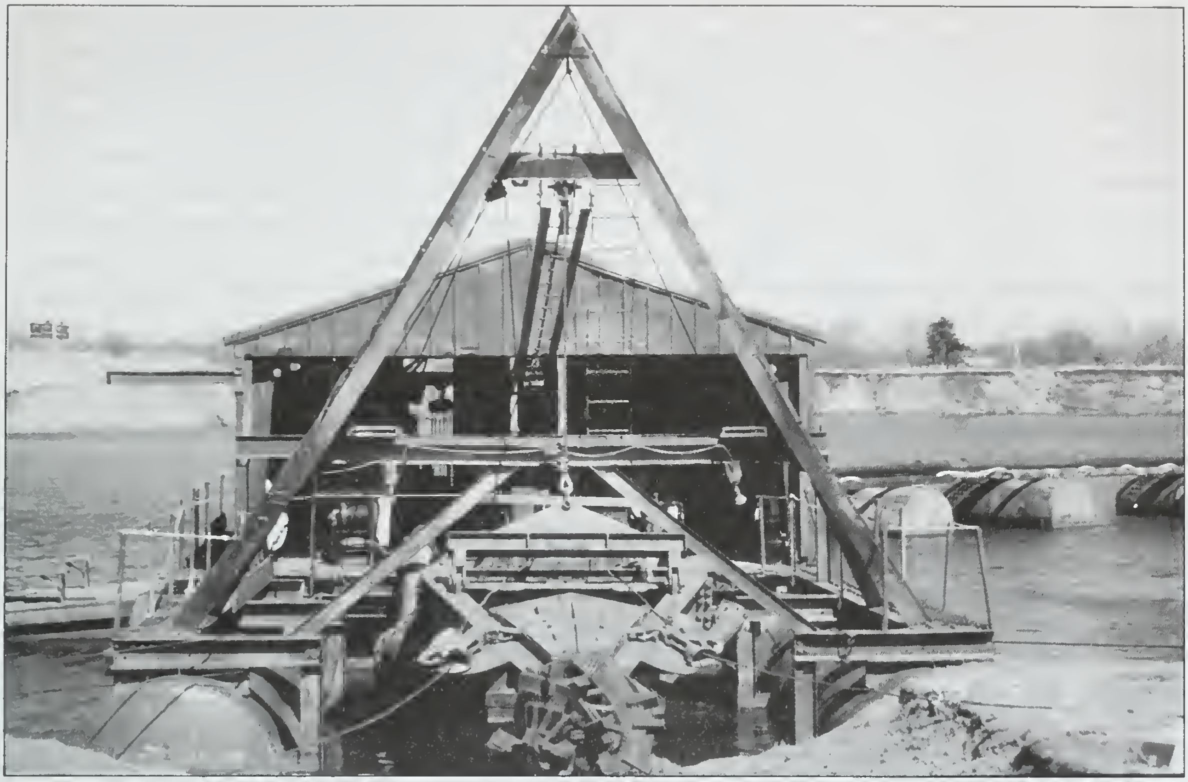


Figure 11 Dredging machine at Moline Consumers, General Sand and Gravel Pit (photo by D. Malone).

Gravel Company at Stop 3. The pit itself is now Potter Lake, separated from the Mississippi River by a narrow peninsula. Originally this area was a low and swampy river floodplain, probably not unlike the wooded shores of the backwater lake that lies along the east side of the park. The park lies outside the levee that protects the city of Rock Island from Mississippi River floodwaters. The levee is located along the northern boundary of the park and connects with a seawall that protects the Rock Island Boat Club, located just to the north. Much of the park was inundated during the Great Flood of 1993.

In 1948 the city of Rock Island purchased 30 acres of land for use as a landfill at the north end of what is now the park. Later this operation was moved to a former gravel pit off 31st Avenue, about ½ mile east of the south end of the park. At that time, development began on that part of the park between Potter Lake and the Mississippi River. Further land purchases in 1953 brought the park to its present size of 244 acres and led to improvements on the east side of Potter Lake and Sunset Marina. The park is the downstream terminus of a bike path that will eventually extend upstream to Savanna, Illinois.

History of the Mississippi River The stretch of river before you is the youngest reach of the upper Mississippi River. It was created when the old channel of the Mississippi River, which flowed southward into central Illinois, was blocked by glacial ice. A large lake developed and subsequently overflowed, forming the Andelusa Gorge. The stream's down-cutting action left a bedrock island (Rock Island) in the river and a series of rapids along the island. These rapids were a major hindrance to commercial river traffic. During the 1800s, goods were offloaded, hauled around the rapids, and loaded onto a different boat to continue the trip. Robert E. Lee's first assignment after graduating from West Point in 1836 was to survey these rapids. In the early 1900s, a series of

gravel bars (wing dams) was constructed partway into the river to force the current to the center and increase the river's depth to 6 feet. During the 1930s, a series of navigation dams and locks was constructed along the Mississippi River to ensure a minimum navigation channel of 9 feet. This field trip stop is at the upstream end of navigation pool 16. Lock and Dam 15 is located just upstream, at the west end of Rock Island. The navigation pools and their dams are numbered downstream from Minneapolis, Minnesota. The Corps of Engineers sometimes must dredge the channel to remove accumulated sand and mud in order to maintain the 9-foot navigation channel mandated by an act of Congress. Credit Island, directly across the channel, is one of numerous islands composed of mud and sand that occur in the Mississippi River from its headwaters to its mouth. Rock Island is the largest bedrock island in the Mississippi River.

The Mississippi River at this point is about 0.4 mile wide. The navigation channel is marked by buoys, each of which is located at the end of a wing dam designed to direct the water into the navigation channel. The stronger flow that results helps keep the channel free of sediment and thus maintains the minimum depth of 9 feet required for navigation. Credit Island Park lies across the river in Davenport, Iowa. From the gazebo it is possible to see the mouth of the Rock River about 1 mile downstream, and the I-280 bridge a little beyond.

Stop 5 Black Hawk State Historic Site (NE, Sec. 14, T17N, R2W, 4th PM, Milan 7.5-Minute Quadrangle, Rock Island County). Park in one of the parking areas and assemble at the A-frame shelter house near the lower parking lot. Note: When visiting the park, use the pedestrian overpass over Black Hawk Road.

History of Black Hawk State Historic Site
The following description is taken from the Illinois Historic Preservation Agency brochure:

> Black Hawk State Historic Site—a wooded, steeply rolling 208-acre tract—borders the Rock River in Rock Island County. Prehistoric Indians and nineteenth-century settlers made their homes here, but the area is most closely identified with the Sauk nation and the warrior-leader whose name it bears—Black Hawk. The site, which is also noted for its many natural features, is managed by the Illinois Historic Preservation Agency.
>
> **Sauk and Mesquakie**
> The Black Hawk site was first occupied by Indians as long as 12,000 years ago, and it was continuously inhabited through the Hopewell period, ca. 100 B.C. to A.D. 250. Villagers lived within the bounds of the present historic site, and they built burial mounds along the bluffs above the river. Unfortunately, the mounds have been destroyed.
>
> For nearly a century beginning about 1730, the Sauk and Mesquakie Indians made their home here. Saukenuk, the capital of the Sauk nation and one of the largest Indian centers in North America, stood adjacent to the site. The Sauk and the Mesquakie farmed the land along the river and relied upon the fur trade for their livelihood. At the height of their power, they controlled parts of Illinois, Wisconsin, and Missouri and all of Iowa.
>
> Saukenuk was the site of the westernmost battle of the Revolutionary War. Americans destroyed the village in 1780 because some of the Sauk had given military support to the British. In 1804, several chiefs of the tribe ceded the village land to

the United States government. The Sauk warrior Black Hawk (he was not a chief) headed the pro-British faction that refused to recognize the cession as legal. During the War of 1812, the pro-British Indians remained at Saukenuk, defeating the Americans in two Mississippi River battles—Campbell's Island and Credit Island.

In the late 1820s, white settlers began to move into the area. By 1831, the Sauk and Mesquakie had been forced across the Mississippi, relinquishing their claim with the promise that they would not return. The warrior Black Hawk, in 1832, led 1,500 followers back into Illinois in an attempt to regain their cornfields. Following several sharp skirmishes, Black Hawk and his followers—men, women, and children—were chased into the wilderness of southern Wisconsin and decisively defeated at the Battle of Bad Axe on August 2, 1832.

Early Recreation Center

From 1882 to 1927, the Watch Tower amusement park occupied the area that would become Black Hawk State Historic Site. Local businessman Bailey Davenport, president and superintendent of the Rock Island and Milan Steam Railway, developed the Watch Tower as a destination for his rail line. Horse-drawn cars were phased out in favor of electric cars in the 1890s, and daily attendance soared as high as 15,000 as people took the streetcar to Watch Tower for concerts, operas, vaudeville, open-air theater, fireworks, bowling, target shooting, outdoor movies (projected on a canvas screen that often flapped in the breeze), balloon ascensions, and amusement rides. The Watch Tower boasted a figure-eight roller coaster (the four loops made it the first of its kind west of Chicago) and the memorable Shoot the Chutes toboggan slide, which was invented in Rock Island. Beginning in 1898, the "Chutes"—flat boats with side runners that slid on a greased track—carried riders down the bluff at speeds of up to 80 miles per hour. After shooting down the slope, the boat bounced across the waters of the Rock River. Then the "conductor" poled the boat back to the slide, and an electric cable hauled it back to the top.

Natural Features

The deciduous hardwood forest and the Rock River provide habitat for a variety of wildlife. Nearly 175 species of birds can be observed during the year, though spring is a favorite time for observing the migrating species. The dominant trees of the upland forest—oaks—are bountiful at Black Hawk, along with a variety of other hardwoods. Numerous wildflowers, shrubs, and vines grow under their canopy. More than 30 wildflower species, including wild orchids (showy orchids), bloom in April and May.

The following is taken from the brochure *Black Hawk*, prepared by the Citizens to Preserve Black Hawk Park Foundation:

"I am a Sauk. . . I am a warrior!" So proclaimed Black Hawk in the spring of 1831, only a few days before he and his followers were forced to leave their home along Rock River forever. Though not a chief by birth, Black Hawk was the recognized leader of a political faction within the Sauk nation that believed in the old ways, the way of life that existed before Europeans came to America. He fought hard to preserve his ancestral home, but, in the end, failed to stem the tide of cultural change brought about by the invading European-Americans.

Ma-ka-tai-me-she-kia-kiak, or Black Sparrow Hawk, was born about 1767 at Saukenuk. This principal Sauk city was located along the Rock River, a few miles from its mouth. Black Hawk was born into the Thunder clan. His father's name was Py-e-sa.

Black Hawk was a member of the warrior class. By the time the Sauk and their allies the Mesquakie (or Fox) had moved to the Rock River region around 1750, warfare had come to play an increasingly important role in tribal affairs. For an ambitious man, the path to success was along the path to war. Black Hawk was 15 years old when he wounded his first enemy in battle. This deed earned Black Hawk the right to paint his face and wear feathers. Time and time again he proved his bravery and skill in battle. As he grew older, he came to be a trusted leader of large war parties.

During the War of 1812, Black Hawk fought on the side of the British. He was a trusted lieutenant of the great Shawnee warrior-leader Tecumseh and fought with his forces at the battle of Detroit in 1813. In this area, Black Hawk and his Sauk followers, known as the British Band, were responsible for the victories at Campbell's Island and Credit Island. Although Black Hawk signed a treaty of peace with the United States government at the end of the war, he refused to relinquish his friendship with the British. Accordingly, every year he and his British Band followed the Great Sauk Trail from Saukenuk to Fort Malden in Amberstburg, Ontario, to receive gifts from the British military officials there.

Though polygamy was practiced among the Sauk, Black Hawk had only one wife, As-she-we-qua, or Singing Bird. They had five children—two girls and three boys. The eldest son and youngest daughter both died in the same year, probably before 1820. Black Hawk mourned their deaths for two years in the traditional Sauk fashion. He built a small house away from the city proper, blackened his face with ashes, and fasted by drinking only water at mid-day and eating a little boiled corn at night.

The Black Hawk War

Black Hawk is best known for the war that bears his name. The Black Hawk War of 1832 was the last Indian war fought east of the Mississippi River. The Indians' defeat spelled the end of 200 years of armed resistance to European-American encroachment on Indian lands.

In 1804, five Sauk and Mesquakie chiefs were tricked into signing a treaty with the United States government, selling tribal lands in Illinois, Missouri, and Wisconsin—nearly 51 million acres—in exchange for various goods and a $1,000 annuity to be paid to the tribes annually. The treaty was clearly illegal by Sauk and Mesquakie custom. The American officials knew this. The United States Senate, however, ratified the treaty in December 1804. The treaty stipulated that the Indians could remain on the ceded lands as long as they were not wanted for white settlement. And so the matter rested for 24 years.

In 1828, white settlers began to move into Saukenuk and its vicinity. They demanded that the Indians now be removed. In order to avoid bloodshed, the majority of the Sauk and Mesquakie moved to the west side of the Mississippi. Black Hawk, however, refused to go. He and his followers remained at Saukenuk, living side by side with white settlers. Many problems ensued. Finally, by June 1831, the Governor of Illinois demanded that the army remove Black Hawk and his British Band. Troops were dispatched. Black Hawk, realizing he was badly outnumbered, slipped across the river during the night of June 25. A few days later he agreed never to return to Illinois.

Black Hawk and his followers were unhappy in the Iowa lands. Black Hawk dreamed of leading an Indian uprising to forcibly retake their lost Illinois home. In April 1832, Black Hawk and about 1500 followers (500 warriors and 1000 women,

children, and old people) crossed the Mississippi to its eastern bank. They followed the course of the Rock River for 50 miles, their objective being a Winnebago town, now called Prophetstown. This move threw the frontier into a panic. The ensuing war, named the Black Hawk War, lasted just 15 weeks. It ended August 2, 1832, at the Battle of Bad Axe, Wisconsin. By the end of the war, approximately two-thirds of Black Hawk's followers were dead—some in battle, most of starvation, deprivation, and exhaustion.

Though Black Hawk escaped before the Battle of Bad Axe, he was captured six weeks later and turned over to American authorities. He and his five closest advisors, including his eldest son, were imprisoned at Jefferson Barracks, Missouri, until April 1833. The group was then taken to Washington, D.C. where Black Hawk met with President Andrew Jackson. He was then sent to Fortress Monroe, Virginia.

Black Hawk and his party were released on May 30, 1833. Prior to their return to Rock Island, they were taken on a tour of large cities on the East Coast, where they were a media sensation. People turned out in droves to see the famous Black Hawk and his warriors. It was during this time that Black Hawk was erroneously tagged a "chief." This was due to a lack of understanding of Sauk politics. The American public reasoned that anyone powerful enough to wage war against the United States must be a chief. The misnomer continues to this day. Though a great warrior and military tactician, Black Hawk was never a chief.

Black Hawk returned to Rock Island in August 1833. Keokuck, Black Hawk's arch political rival, met the party at Fort Armstrong, where Black Hawk was released into Keokuck's custody. It was here made plain that the United States recognized Keokuck as chief of the Sauk. Black Hawk was directed to follow Keokuck's counsel and advice. Black Hawk's humiliation was complete.

Black Hawk was a tired, broken old man. The war had been a disaster and more than 1,000 of his people had died. Through his attempt to save his people's traditions and homeland, he had brought only dishonor upon himself. In the treaty that ended the war, the Sauk and Mesquakie were forced to cede still more land to the United States as war reparation.

Shortly after his return, Black Hawk dictated his autobiography to Antoine LeClaire, a government interpreter living at Fort Armstrong. The *Life of Black Hawk* was published in 1833. It sold well. Though disgraced among his own people, Black Hawk had achieved fame and admiration among the European-Americans, his former enemies. Such was the tragedy and irony of his final years.

For the next five years, Black Hawk lived along the Iowa River with his wife and children. They moved to a new home along the Des Moines River in 1838. It was here that he died on October 3, 1838, of a respiratory illness. He was 71 years old.

Black Hawk was buried sitting up inside a small mausoleum of logs. His grave was soon robbed, but eventually his remains were deposited in a museum of Burlington, Iowa. The museum and its contents were destroyed by fire in 1855.

Black Hawk fought hard to preserve the ancestral home of his people, as well as their time-honored customs and traditions. Unfortunately, he was born at a time when the ancient ways of his people were fast crumbling before the cultural pressure of the New Americans. The fate of Black Hawk and his nation was a tragic outcome of the clash of two divergent cultures.

"Sinissippi (Rock River) was a beautiful country. I loved it, my cornfields and the home of my people. I fought for them."

Geology of Black Hawk State Historic Site

See figure 12 for a detailed map of park trails and the location of A to E and the Sears site.

Rock River Valley Looking south from the back of the lodge, near the stature of Black Hawk, is a magnificent view of the Rock River Valley. We often think that a river valley is only the trench in which there is actually water, but the valley of an old river is much wider. A valley is formed by the eroding action of the river that flows in it. The size of the valley is a rough measure of its age. The older it is, the wider and deeper it is. The Rock River valley at this point is about 2 miles across. You are standing on one of the bluffs that forms the valley wall. The low ground below is the floodplain. Often the floodplain contains terraces and levees. The river itself flows in the channel. A topographic cross section of the valley is given in figure 5.

From the bluff, looking down at Rock River, you can see a limestone quarry on Vandruff Island. This quarry is mining the Devonian-age limestone, which was deposited approximately 375 millions years ago. The quarry below is about as deep as the bluffs are high.

Geology in the Park Black Hawk State Historic Site consists of two distinct geologic areas. The first area is the east–west-trending ridge located between Black Hawk Road and Rock River. This ridge is composed of the Caseyville Formation sandstone (fig. 13). The sandstone provides internal strength to this ridge and is visible along the bluff trail. This sedimentary rock is composed of sand particles that were deposited by moving water. These particles were then cemented together by iron oxide that was deposited by water seeping through the sand. Sandstones often show distinct layering because the amount and type of materials deposited varied from time to time. This sandstone was formed between 300 and 280 million years ago, during the Pennsylvanian Period of geologic time, when the Appalachian Mountains were being uplifted. Sediments from the mountains were washed away and spread into river deltas along an inland sea. Over millions of years, these sediments were compressed into shale, siltstone, and sandstone.

The upper and lower Caseyville sandstones in the bluffs represent two different environments of deposition. The upper horizon consists of 3 to 5 feet of fine- to medium-size sand grains deposited as a near-horizontal sheet deposit. This sheet deposit is present from location A to east of location E. The lower horizon consists of cross-bedded, fine- to coarse-size sand grains deposited in a channel. The channel sandstone is present at location C and the Sears site. Although the sandstone provides strength to the ridge, slump features are present all along the bluff above Rock River.

This sandstone ridge was the site of the winter encampment of the Sauk and Fox Indians during the late 1700s and early 1800s. The museum has an excellent depiction of Indian life. We recommend a tour of the museum as part of this field trip. The ridge was also the site of an amusement park from 1882 until the 1920s. The footings for the "shoot the Chutes" are still evident near location E. Years later, a similar ride gained fame at the Six Flags amusement park as the Log Flume.

From the river to the top of the bluff, the exposed rocks were deposited during three different geological periods (fig. 13).

1. Devonian – 400 to 350 million years ago. During the Devonian period, when Illinois was located south of the equator, a warm, shallow sea covered this area. It left the Cedar Valley Limestone, now visible up to 10

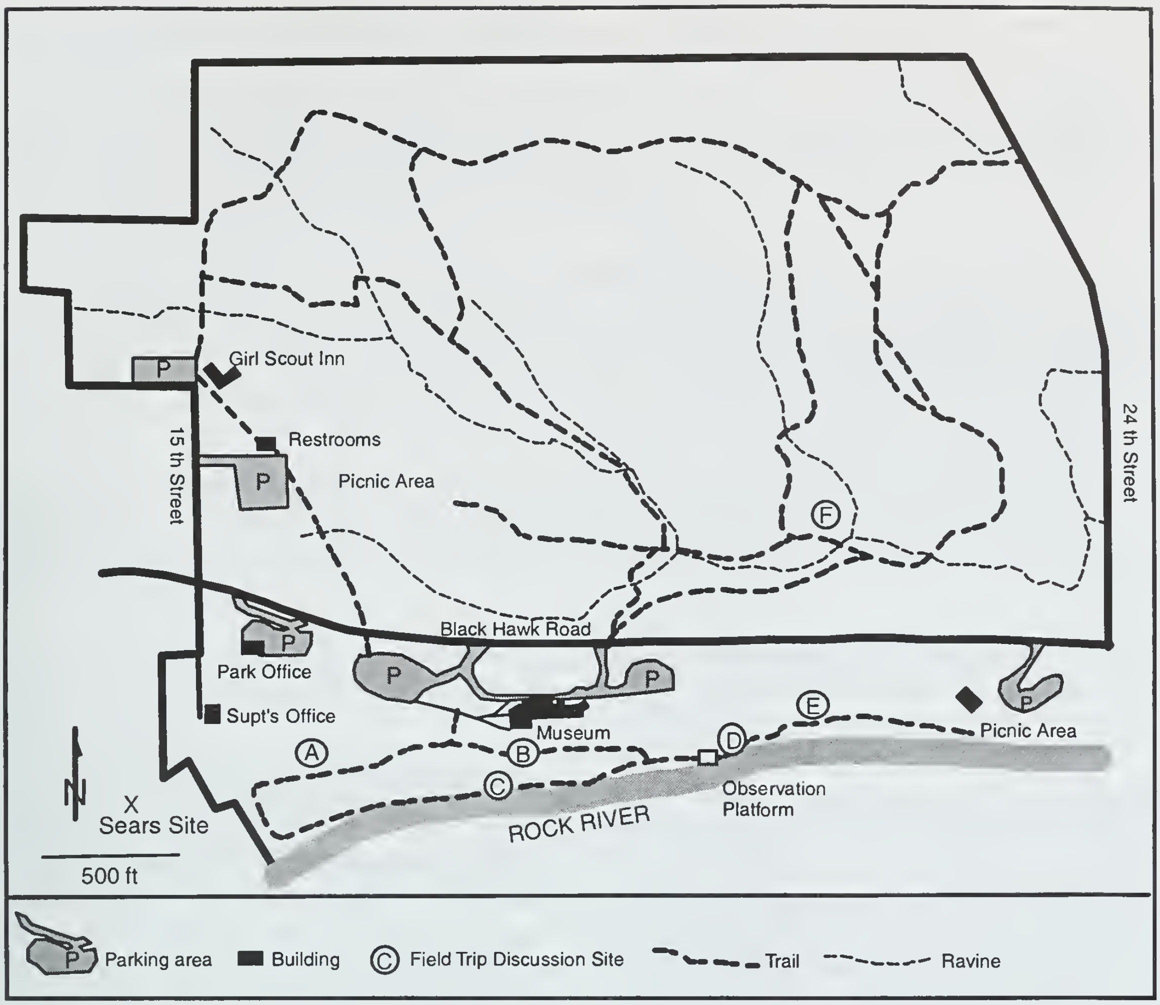
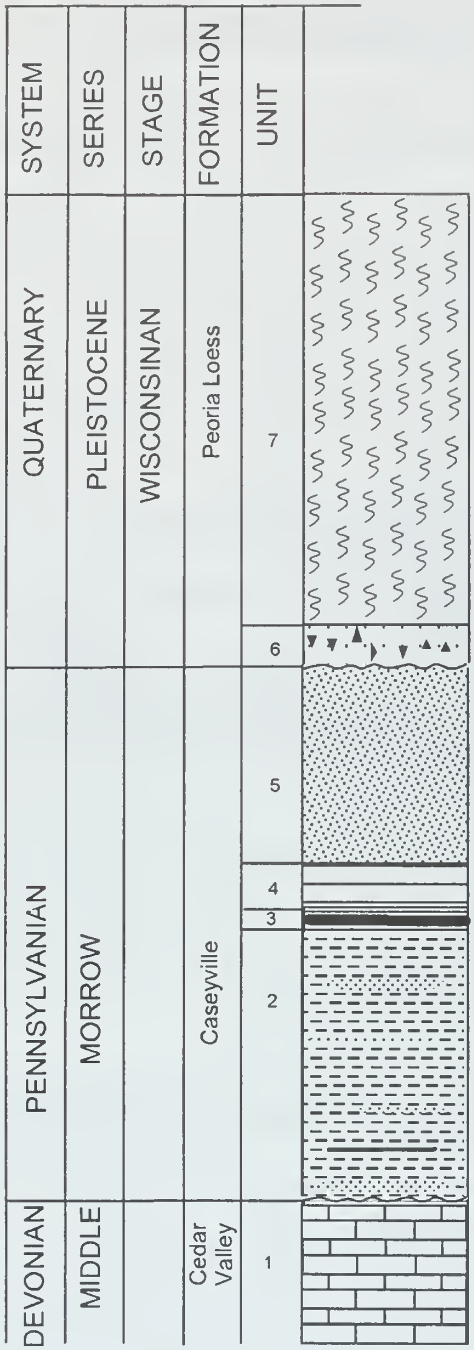


Figure 12 Black Hawk State Historic Site – trail map with field trip stops indicated.

Limestone, now visible up to 10 feet above the river on the lower trail. Around 350 million years ago, this sea began to recede.

2. Pennsylvanian – 300 to 280 million years ago. During the Pennsylvanian period, an inland sea covered most of the midwest. At the same time, the Appalachian Mountains were being uplifted. Sediment from this uplift spread into river deltas. Overtime, this sediment was com pressed into sandstone. Plants growing in swampy areas along the coasts of the inland sea became a fossil fuel known as coal. Illinois was then located close to the equator, which made the climate tropical.

3. Pleistocene – 2,000,000 to 10,000 years ago. During the ice age, glaciers left glacial till on top of the sandstone. The till deposits here at the park are about 150,000 years old. Finally, loess, a silty deposit, was blown over everything, thus completing the 100-foot-high bluff.



7. Silt, yellowish-brown, calcareous, modern soil at top. Thickness = ~ 50 feet.

6. Till, silty, reddish-brown, clayey, scattered pebbles, leached. Thickness = 1.5 feet.

5. Sandstone, light brown, medium to fine grained with irregular streaks of carbonaeous shale. Thickness = 12–25 feet.

4. Shale, gray, fissil, silty. Thickness = 3 feet.

3. Coal, impure, shale partings. Thickness = 1 foot.

2. Shale, dark gray with silty lenses and thin streaks, grades from fissile shale in thin beds to blocky claystone in massive beds. Thickness = 46 feet.

1. Limestone (wackestone), light gray, surface is stained red-brown, abundant crinoids, base concealed. Thickness = >10 feet.

Figure 13 Stratigraphic column for Black Hawk State Historic Site.

Some of the geological features that can be observed in the park include;

Location A – slump terrace A large block of sandstone measuring approximately 20 to 25 feet wide and more than 100 feet long has slumped (moved downhill) 5 to 6 feet. The sandstone sits on top of a shale unit. When the shales become wet, they form a lubricated slide plane, which allows blocks of sandstone to slump downhill because of gravity.

Location B – sandstone overhang (fig. 14) Glaciers, wind, and water erode away weaker rocks, forming rock shelters and small overhangs. The erosion of weaker layers of sandstone formed this overhang. The combination of penetrating plant roots and seeping water weakens the rock. Notice the collapsed layer on the ground. Rainwater is actively eroding away the stone. A small vein of coal is located near the bottom of the overhang.

Location C – channel sandstone The Caseyville sandstone at this location consists of cross-bedded, fine- to coarse-size sand grains deposited in a channel. The channel sandstones are easily recognized by their concave geometry. If you use your imagination, this sandstone outcrop looks like it is smiling at you.

Location D – slumping of unconsolidated colluvium and the smearing of sediments The slumping at this location is evidence of slope instability and failure where Pennsylvanian shale is present in the bluffs.

Just west of location D is an observation platform. The rock exposed just below the observation platform is the Cedar Valley limestone, the oldest exposed rock in the park. This limestone was deposited during the Devonian Period of geologic time, about 375 million years ago. Illinois was located south of the equator at that time and was covered by a tropical, inland sea. The Cedar Valley Limestone was deposited in warm, shallow, well-aerated seas. Brachiopods, crinoids, corals, bryozoans, algae, and trilobites are the more common fossils found in it. These fossils attest to the fact that a sea was once located here. Limestone is a sedimentary rock that formed from the shells of organisms that live in warm, shallow seas. Mud from the bottom of the sea and fossil material are cemented together by calcium carbonate. Limestone occurs throughout the midwest.

A broken sewer line is located between location D and the Picnic Area. There was sufficient leakage from the broken sewer line that a lift station was constructed at the picnic area to feed a temporary, 24-inch-diameter, aboveground PVC line that extends westward to an invert at location D (fig. 15). The Cedar Valley Limestone occurs at or above river level from location D to the Sears site just west of the park. The limestone provides stability to the lower part of the slope; the sewer line is therefore unbroken west of location D.

Location E – rotated sandstone strata (fig. 16) This is the largest sandstone outcropping on the trail. Notice the layering, the angles of various layers, and the colors—especially white from precipitated salts and reds and browns from the oxidized (rusted) iron.

The unusual tilted layering, or stratification, visible at this point was caused by two different phenomena. The original tilt occurred as the sediment was deposited during the Pennsylvanian age. The sediment was deposited on the downstream side of a river bar. The flowing water affected the angle of the deposits. The sandstone block has tilted again more recently, probably because it rests on slippery, muddy shale. When saturated with water, the shale turns to a greasy mud, allowing the sandstone to slide—which is why the angle of the tilt inclines back toward the bluff.

Figure 14 Geologist "Skip" Nelson points to small sandstone overhang (rock shelter) at base of Caseyville sandstone at location B (photo by D. Malone).

Figure 15 Aboveground sewer line at location D (photo by D. Malone).

Figure 16 Rotated blocks of Caseyville sandstone at location E. Geologist "Skip" Nelson points to crossbedded sandstone (photo by D. Malone).

A spring flows from the base of the sandstone near location E. This spring is an indication of the water underground that caused the sandstone to slump. Sandstone is porous. As water moves through the sandstone, it reaches impermeable clay below. The water then moves laterally, slowly seeping out as a spring. The ground underneath is thus constantly full of water. The wooden walkway upon which you are standing was constructed when a portion of the trail collapsed after a very heavy rainfall.

Above the outcropping of sandstone is a wind-blown soil called loess (pronounced "luss"). It was deposited 20,000 to 13,000 years ago, during the last glacial episode. Loess is silt that was produced by the grinding action of the glaciers. It was carried away by melt water from the glacial front, deposited in floodplains of major rivers, such as the Mississippi, and then blown across the landscape. It serves as the parent material for the rich farm soils of the Midwest.

This is the last stop on this section of the trail. The Rock River picnic area is located to the east.

Sears Site The Sears site is located just west of the park with access off 50th Avenue. On the day of the field trip, we will access the Sears site by following the base of the bluffs along the southwest corner of the park boundary. The Cedar Valley Limestone is present 20 feet above river level. Large crinoid columnals are common in the limestone. The Cedar Valley Limestone is overlain by a few feet of mudstone. The thin sandstone that occurs above the mudstone is of interest because it contains imprints of Pennsylvanian-age tree roots and branches.

Location F The second distinct geologic area is located north of Black Hawk Road. This area is part of the stream-dissected uplands that compose Rock Island. Before establishment of the Mississippi River in its present position, Coal Creek, located along the east edge of the park boundary, drained southward into Rock River. Coal Creek and its tributaries cut down through relatively weak materials, creating a small drainage basin with about 100 feet of local relief. This large amount of local relief contrasts with the relief of the much younger and smaller drainage basins that flow into the Mississippi River in the area.

Down-cutting by one of the tributaries of Coal Creek has exposed a 2-inch-thick coal bed about 30 feet southwest of location F. This is the same coal that is just a thin layer near location D. A thicker, older, and deeper coal was mined underground in 1876 at location F. The coal was loaded on a narrow-gauge railroad and hauled north into Rock Island. This mine was only marginally economical and was closed when better quality coal available from mines in Carbon Cliff and Coal Valley.

Coals in Rock Island County are variable in both thickness and quality. The thickness is dependent on the topography of the underlying pre-Pennsylvanian surface. The thickest and highest quality coals accumulated in the lowest areas and were absent where the Cedar Valley Limestone stood topographically high. Two coals were mined in this area. The Rock Island Coal was mined at several locations in Coal Valley and Carbon Cliff. The older and deeper coal was mined only here and in the area between the Niabi Zoo and Coal Valley.

The Pennsylvanian-age strata here present an interesting problem. Why were relatively old Pennsylvanian sediments deposited and preserved in this area but nowhere else within 50 miles of here, and why are Caseyville coals present at Black Hawk at elevations higher than the Rock Island Coal near Coal Valley?

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GLOSSARY

The following definitions are adapted in total or in part from several sources; the principal source is R.L. Bates and J.A Jackson, eds.,Glossary of Geology, 3rd ed.: American Geological Institute, Alexandria, VA, 1987, 788 p.

Ablation - Separation and removal of rock material and formation of deposits, especially by wind action or the washing away of loose and soluble materials.

Age - An interval of geologic time; a division of an epoch.

Aggrading stream - One that is actively depositing sediment in its channel or floodplain because it is being supplied with more load than it can transport.

Alluviated valley - One that has been at least partially filled with sand, silt, and mud by flowing water.

Alluvium - A general term for clay, silt, sand, gravel, or similar unconsolidated sorted or semisorted sediment deposited during comparatively recent time by a stream or other body of running water.

Anticline - A convex-upward rock fold in which strata have been bent into an arch; the strata on either side of the core of the arch are inclined in opposite directions away from the axis or crest; the core contains older rocks than does the perimeter of the structure.

Aquifer - A geologic formation that is water-bearing and which transmits water from one point to another.

Argillaceous - Said of rock or sediment that contains, or is composed of, clay-sized particles or clay minerals.

Arenite - A relatively clean quartz sandstone that is well sorted and contains less than 10% argillaceous material.

Base level - Lower limit of erosion of the land's surface by running water. Controlled locally and temporarily by the water level of stream mouths emptying into lakes, or more generally and semipermanently by the level of the ocean (mean sea level).

Basement complex - The suite of mostly crystalline igneous and/or metamorphic rocks that generally underlies the sedimentary rock sequence.

Basin - A topographic or structural low area that generally receives thicker deposits of sediments than adjacent areas; the low areas tend to sink more readily, partly because of the weight of the thicker sediments; the term also denotes an area of relatively deep water adjacent to shallow-water shelf areas.

Bed - A naturally occurring layer of earth material of relatively greater horizontal than vertical extent that is characterized by physical properties different from those of overlying and underlying materials. It also is the ground upon which any body of water rests or has rested, or the land covered by the waters of a stream, lake, or ocean; the bottom of a stream channel.

Bedrock - The solid rock (sedimentary, igneous, or metamorphic) that underlies the unconsolidated (non-indurated) surface materials (for example, soil, sand, gravel, glacial till, etc.).

Bedrock valley - A drainageway eroded into the solid bedrock beneath the surface materials. It may be completely filled with unconsolidated (non-indurated) materials and hidden from view.

Braided stream - A low-gradient, low-volume stream flowing through an intricate network of interlacing shallow channels that repeatedly merge and divide, and are separated from each other by branch islands or channel bars. Such a stream may be incapable of carrying all of its load. Most streams that receive more sediment load than they can carry become braided.

Calcarenite - Describes a limestone composed of more or less worn fragments of shells or pieces of older limestone. The particles are generally sand-sized.

Calcareous - Said of a rock containing some calcium carbonate ($CaCO_3$), but composed mostly of something else; (synonym: limey).

Calcining - The heating of calcite or limestone to its temperature of dissociation so that it loses its carbon dioxide; also applied to the heating of gypsum to drive off its water of crystallization to make plaster of paris.

Calcite - A common rock-forming mineral consisting of $CaCO_3$; it may be white, colorless, or pale shades of gray, yellow, and blue; it has perfect rhombohedral cleavage, appears vitreous, and has a hardness of 3 on the Mohs scale; it effervesces (fizzes) readily in cold dilute hydrochloric acid. It is the principal constituent of limestone.

Chert - Silicon dioxide (SiO_2); a compact, massive rock composed of minute particles of quartz and/or chalcedony; it is similar to flint, but lighter in color.

Clastic - Said of rocks composed of particles of other rocks or minerals, including broken organic hard parts as well as rock substances of any sort, transported and deposited by wind, water, ice or gravity.

Closure - The difference in altitude between the crest of a dome or anticline and the lowest structural or elevation contour that completely surrounds it.

Columnar section - A graphic representation, in the form of one or more vertical column(s), of the vertical succession and stratigraphic relations of rock units in a region.

Conformable - Said of strata deposited one upon another without interruption in accumulation of sediment; beds parallel.

Delta - A low, nearly flat, alluvial land form deposited at or near the mouth of a river where it enters a body of standing water; commonly a triangular or fan-shaped plain extending beyond the general trend of a coastline.

Detritus - Loose rock and mineral material produced by mechanical disintegration and removed from its place of origin by wind, water, gravity, or ice; also, fine particles of organic matter, such as plant debris.

Disconformity - An *unconformity* marked by a distinct erosion-produced irregular, uneven surface of appreciable relief between parallel strata below and above the break; sometimes represents a considerable time interval of nondeposition.

Dolomite - A mineral, calcium-magnesium carbonate ($Ca,Mg[CO_3]_2$); also the name applied to sedimentary rocks composed largely of the mineral. It is white, colorless, or tinged yellow, brown, pink, or gray; has perfect rhombohedral cleavage; appears pearly to vitreous; effervesces feebly in cold dilute hydrochloric acid.

Drift - All rock material transported by a glacier and deposited either directly by the ice or reworked and deposited by meltwater streams and/or the wind.

Driftless Area - A 10,000-square-mile area in northeastern Iowa, southwestern Wisconsin, and northwestern Illinois where the absence of glacial drift suggests that the area may not have been glaciated.

End moraine - A ridge or series of ridges formed by accumulations of drift built up along the outer margin of an actively flowing glacier at any given time; a moraine that has been deposited at the lower or outer end of a glacier.

Epoch - An interval of geologic time; a division of a period. (Example: Pleistocene Epoch).

Era - The unit of geologic time that is next in magnitude beneath an eon; it consists of two or more periods. (Example: Paleozoic Era).

Escarpment - A long, more or less continuous cliff or steep slope facing in one general direction; it generally marks the outcrop of a resistant layer of rocks, or the exposed plane of a fault that has moved recently.

Fault - A fracture surface or zone of fractures in Earth materials along which there has been vertical and/or horizontal displacement or movement of the strata on opposite sides relative to one another.

Flaggy - Said of rock that tends to split into layers of suitable thickness for use as flagstone.

Flood plain - The surface or strip of relatively smooth land adjacent to a stream channel produced by the stream's erosion and deposition actions; the area covered with water when the stream overflows its banks at times of high water; it is built of alluvium carried by the stream during floods and deposited in the sluggish water beyond the influence of the swiftest current.

Fluvial - Of or pertaining to a river or rivers.

Formation - The basic rock unit, one distinctive enough to be readily recognizable in the field and widespread and thick enough to be plotted on a map. It describes the strata, such as limestone, sandstone, shale, or combinations of these and other rock types. Formations have formal names, such as Joliet Formation or St. Louis Limestone (Formation), generally derived from the geographic localities where the unit was first recognized and described.

Fossil - Any remains or traces of a once-living plant or animal preserved in rocks (arbitrarily excludes Recent remains); any evidence of ancient life. Also used to refer to any object that existed in the geologic past and for which evidence remains (for example, a fossil waterfall)

Friable - Said of a rock or mineral that crumbles naturally or is easily broken, pulverized, or reduced to powder, such as a soft and poorly cemmented sandstone.

Geology - The study of the planet Earth that is concerned with its origin, composition, and form, its evolution and history, and the processes that acted (and act) upon it to control its historic and present forms.

Geophysics - Study of the Earth with quantitative physical methods. Application of the principles of physics to the study of the earth, especially its interior.

Glaciation - A collective term for the geologic processes of glacial activity, including erosion and deposition, and the resulting effects of such action on the Earth's surface.

Glacier - A large, slow-moving mass of ice formed on land by the compaction and recrystallization of snow.

Gradient - A part of a surface feature of the Earth that slopes upward or downward; the angle of slope, as of a stream channel or of a land surface, generally expressed by a ratio of height versus distance, a percentage or an angular measure from the horizontal.

Igneous - Said of a rock or mineral that solidified from molten or partly molten material (that is, from magma).

Indurated - Said of compact rock or soil hardened by the action of pressure, cementation and, especially, heat.

Joint - A fracture or crack in rocks along which there has been no movement of the opposing sides (see also *Fault*).

Karst - Collective term for the land forms and subterranean features found in areas with relatively thin soils underlain by limestone or other soluble rocks; characterized by many sinkholes separated by steep ridges or irregular hills. Tunnels and caves formed by dissolution of the bedrock by groundwater honeycomb the subsurface. Named for the region around Karst in the Dinaric Alps of Croatia where such features were first recognized and described.

Lacustrine - Produced by or belonging to a lake.

Laurasia - A protocontinent of the Northern Hemisphere, corresponding to Gondwana in the Southern Hemisphere, from which the present continents of the Northern Hemisphere have been derived by separation and continental displacement. The supercontinent from which both were derived is Pangea. Laurasia included most of North America, Greenland, and most of Eurasia, excluding India. The main zone of separation was in the North Atlantic, with a branch in Hudson Bay; geologic features on opposite sides of these zones are very similar.

Lava - Molten, fluid rock that is extruded onto the surface of the Earth through a volcano or fissure. Also the solid rock formed when the lava has cooled.

Limestone - A sedimentary rock consisting primarily of calcium carbonate (the mineral, calcite). Limestone is generally formed by accumulation, mostly in place or with only short transport, of the shells of marine animals, but it may also form by direct chemical precipitation from solution in hot springs or caves and, in some instances, in the ocean.

Lithify - To change to stone, or to petrify; especially to consolidate from a loose sediment to a solid rock.

Lithology - The description of rocks on the basis of their color, structure, mineral composition, and grain size; the physical character of a rock.

Local relief - The vertical difference in elevation between the highest and lowest points of a land surface within a specified horizontal distance or in a limited area.

Loess - A homogeneous, unstratified accumulation of silt-sized material deposited by the wind.

Magma - Naturally occurring molten rock material generated within Earth and capable of intrusion into surrounding rocks or extrusion onto the Earth's surface. When extruded on the surface it is called lava. The material from which igneous rocks form through cooling, crystallization, and related processes.

Meander - One of a series of somewhat regular, sharp, sinuous curves, bends, loops, or turns produced by a stream, particularly in its lower course where it swings from side to side across its valley bottom.

Meander scars - Crescent-shaped swales and gentle ridges along a river's flood plain that mark the positions of abandoned parts of a meandering river's channel. They are generally filled in with sediments and vegetation and are most easily seen in aerial photographs.

Metamorphic rock - Any rock derived from pre-existing rocks by mineralogical, chemical, and structural changes, essentially in the solid state, in response to marked changes in temperature, pressure, shearing stress, and chemical environment at depth in Earth's crust (for example, gneisses, schists, marbles, quartzites, etc.)

Mineral - A naturally formed chemical element or compound having a definite chemical composition, an ordered internal arrangement of its atoms, and characteristic crystal form and physical properties.

Monolith - (a) A piece of unfractured bedrock, generally more than a few meters across. (b) A large upstanding mass of rock.

Moraine - A mound, ridge, or other distinct accumulation of glacial drift, predominantly till, deposited in a variety of topographic land forms that are independent of control by the surface on which the drift lies (see also *End Moraine*).

Morphology - The scientific study of form, and of the structures and development that influence form; term used in most sciences.

Natural gamma log - One of several kinds of measurements of rock characteristics taken by lowering instruments into cased or uncased, air- or water-filled boreholes. Elevated natural gamma radiation levels in a rock generally indicate the presence of clay minerals.

Nickpoint - A place with an abrupt inflection in a stream profile, generally formed by the presence of a rock layer resistant to erosion; also, a sharp angle cut by currents at base of a cliff.

Nonconformity - An unconformity resulting from deposition of sedimentary strata on massive crystalline rock.

Outwash - Stratified glacially derived sediment (clay, silt, sand, gravel) deposited by meltwater streams in channels, deltas, outwash plains, on flood plains, and in glacial lakes.

Outwash plain - The surface of a broad body of outwash formed in front of a glacier.

Oxbow lake - A crescent-shaped lake in an abandoned bend of a river channel. A precursor of a meander scar.

Pangea - The supercontinent that existed from 300 to 200 million years ago. It combined most of the continental crust of the Earth, from which the present continents were derived by fragmentation and movement away from each other by means of plate tectonics. During an intermediate stage of the fragmentation, between the existence of Pangea and that of the present widely separated continents, Pangea was split into two large fragments, *Laurasia* on the north and *Gondwana* in the southern hemisphere.

Ped - Any naturally formed unit of soil structure (for example, granule, block, crumb, or aggregate).

Peneplain - A land surface of regional scope worn down by erosion to a nearly flat or broadly undulating plain.

Period - An interval of geologic time; a division of an era (for example, Cambrian, Jurassic, Tertiary).

Physiography - The study and classification of the surface features of Earth on the basis of similarities in geologic strucure and the history of geologic changes.

Physiographic province (or division) - (a) A region, all parts of which are similar in geologic structure and climate and which has consequently had a unified geologic history. (b) Aa region whose pattern of relief features or landforms differs significantly from that of adjacent regions.

Point bar - A low arcuate ridge of sand and gravel developed on the inside of a stream meander by accumulation of sediment as the stream channel migrates toward the outer bank.

Radioactivity logs - Any of several types of geophysical measurements taken in bore holes using either the natural radioactivity in the rocks, or the effects of radiation on the rocks to determine the lithology or other characteristics of the rocks in the walls of the borehole. (Examples: natural gamma radiation log; neutron density log).

Relief - (a) A term used loosely for the actual physical shape, configuration, or general uneveness of a part of Earth's surface, considered with reference to variations of height and slope or to irregularities of the land surface; the elevations or differences in elevation, considered collectively, of a land surface (frequently confused with topography). (b) The vertical difference in elevation between the hilltops or mountain summits and the lowlands or valleys of a given region; "high relief" has great variation; "low relief" has little variation.

Rift - A long narrow trough, generally on a continent, bounded by normal faults, a graben with regional extent. Formed in places where the forces of plate tectonics are beginning to split a continent. (Example: East African Rift Valley).

Sediment - Solid fragmental matter, either inorganic or organic, that originates from weathering of rocks and is transported and deposited by air, water, or ice, or that is accumulated by other natural agents, such as chemical precipitation from solution or secretion from organisms. When deposited, it generally forms layers of loose, unconsolidated material (for example, sand, gravel, silt, mud, till, loess, alluvium).

Sedimentary rock - A rock resulting from the consolidation of loose sediment that has accumulated in layers (for example, sandstone, siltstone, mudstone, limestone).

Shoaling - Said of an ocean or lake bottom that becomes progressively shallower as a shoreline is approached. The shoaling of the ocean bottom causes waves to rise in height and break as they approach the shore.

Sinkhole - Any closed depression in the land surface formed as a result of the collapse of the underlying soil or bedrock into a cavity. Sinkholes are common in areas where bedrock is near the surface and susceptible to dissolution by infiltrating surface water. Sinkhole is synonymous with "doline," a term used extensively in Europe. The essential component of a hydrologically active sinkhole is a drain that allows any water that flows into the sinkhole to flow out the bottom into an underground conduit.

Slip-off slope - Long, low, gentle slope on the inside of a stream meander. The slope on which the sand that forms point bars is deposited.

Stage, substage - Geologic time-rock units; the strata formed during an age or subage, respectively. Generally applied to glacial episodes (for example, to the Woodfordian Substage of the Wisconsinan Stage.

Stratigraphy - The study, definition, and description of major and minor natural divisions of rocks, particularly the study of their form, arrangement, geographic distribution, chronologic succession, naming or classification, correlation, and mutual relationships of rock strata.

Stratigraphic unit - A stratum or body of strata recognized as a unit in the classification of the rocks of Earth's crust with respect to any specific rock character, property, or attribute or for any purpose such as description, mapping, and correlation.

Stratum - A tabular or sheet-like mass, or a single, distinct layer of material of any thickness, separable from other layers above and below by a discrete change in character of the material or by a sharp physical break, or by both. The term is generally applied to sedimentary rocks, but could be applied to any tabular body of rock. (See also *Bed*)

Subage - A small interval of geologic time; a division of an age.

Syncline - A convex-downward fold in which the strata have been bent to form a trough; the strat on either side of the core of the trough are inclined in opposite directions toward the axis of the fold; the core area of the fold contains the youngest rocks. (See also *Anticline*).

System - A fundamental geologic time-rock unit of worldwide significance; the strata of a system are those deposited during a period of geologic time (for example, rocks formed during the Pennsylvanian Period are included in the Pennsylvanian System).

Tectonic - Pertaining to the global forces that cause folding and faulting of the Earth's crust. Also used to classify or describe features or structures formed by the action of those forces.

Tectonics - The branch of geology dealing with the broad architecture of the upper (outer) part of Earth; that is, the major structural or deformational features, their origins, historical evolution, and relations to each other. It is similar to structural geology, but generally deals with larger features such as whole mountain ranges, or continents.

Temperature-resistance log - A borehole log, run only in water-filled boreholes, that measures the water temperature and the quality of groundwater in the well.

Terrace - An abandoned floodplain formed when a stream flowed at a level above the level of its present channel and floodplain.

Till - Unlithified, nonsorted, unstratified drift deposited by and underneath a glacier and consisting of a heterogenous mixture of different sizes and kinds of rock fragments.

Till plain - The undulating surface of low relief in an area underlain by ground moraine.

Topography - The natural or physical surface features of a region, considered collectively as to form; the features revealed by the contour lines of a map.

Unconformable - Said of strata that do not succeed the underlying rocks in immediate order of age or in parallel position. A general term applied to any strata deposited directly upon older rocks after an interruption in sedimentation, with or without any deformation and/or erosion of the older rocks.

Unconformity - A surface of erosion or nondeposition that separates younger strata from older strata; most unconformities indicate intervals of time when former areas of the sea bottom were temporarily raised above sea level.

Valley trains - The accumulations of outwash deposited by rivers in their valleys downstream from a glacier.

Water table - The point in a well or opening in the Earth where groundwater begins. It generally marks the top of the zone where the pores in the surrounding rocks are fully saturated with water.

Weathering - The group of processes, both chemical and physical, whereby rocks on exposure to the weather change in character, decay, and finally crumble into soil.

EXOTIC ROCKS or Erratics Are Erratic

Here and there in Illinois are boulders lying alone or with companions in the corner of a field or someone's yard, on a courthouse lawn or a schoolyard. Many of them—colorful and glittering granites, banded gneisses, and other intricately veined and streaked igneous and metamorphic rocks—seem out of place in the stoneless, grassy knolls and prairies of our state. Their "erratic" occurrence is the reason for their interesting name.

A piece of Canada sitting in central Illinois (photo by D. Reinertsen).

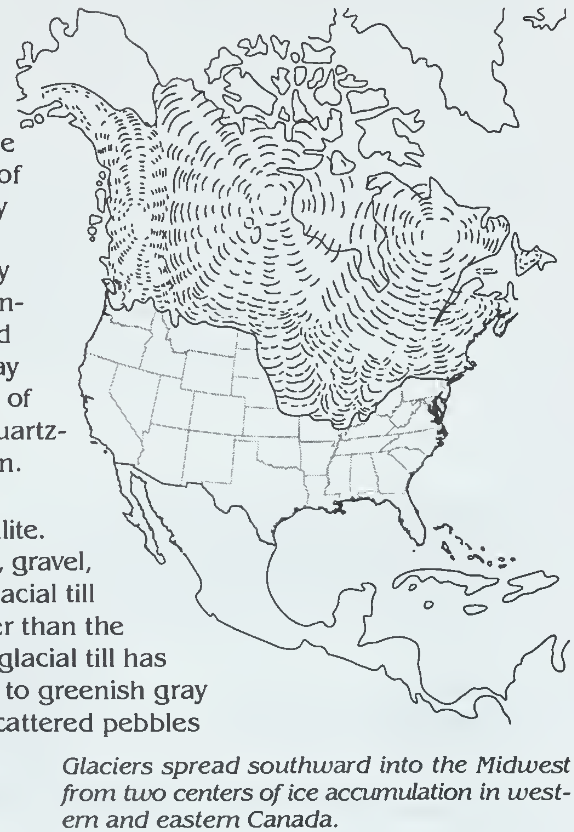
Where did erratics come from?

These exotic rocks came from Canada and the states north of us. The continental glaciers of the Great Ice Age scoured and scraped the land surface as they advanced, pushing up chunks of bedrock and grinding them against each other or along the ground surface as the rock-laden ice sheets pushed southward.

Sometimes you can tell where the erratic originally came from by determining the kind of rock it is. A large boulder of granite, gneiss, or other igneous or metamorphic rock may have come from Canada.

Some erratics containing flecks of copper were probably transported here from the "Copper Range" of the upper peninsula of Michigan. Large pieces of copper have been found in glacial deposits of central and northern Illinois. Light gray to white quartzite boulders with beautiful, rounded pebbles of red jasper came from Ontario, Canada. Purplish pieces of quartzite, some of them banded, probably originated in Wisconsin.

Most interesting are the few large boulders of Canadian tillite. Glacial till is an unsorted and unlayered mixture of clay, sand, gravel, and boulders that vary widely in size and shape. Tillite is glacial till that was deposited by a glacier many millions of years older than the ones that invaded our state during the Great Ice Age. This glacial till has been around so long that it has been hardened into a gray to greenish gray rock containing a mixture of grains of different sizes and scattered pebbles of various types and sizes.



Glaciers spread southward into the Midwest from two centers of ice accumulation in western and eastern Canada.

How did erratics get here?

Many boulders were probably dropped directly from the melting front of the glacier. Others may have been rafted to their present resting places by icebergs in ancient lakes or on floodwaters of some long-vanished stream as it poured from a glacier. Still others, buried in the glacial deposits, could have worked their way up to the land surface as the surrounding loose soil repeatedly froze and thawed. When the freezing ground expands, pieces of rock tend to be pushed upward, where they are more easily reached by the farmer's plow and also more likely to be exposed by erosion.

Keep an eye out for erratics. You may find some of these glacial strangers in your neighborhood.

Many erratics are of notable size and beauty. Some are used as monuments in courthouse squares and parks, or along highways. Many are marked with metal plaques to indicate an interesting historical spot or event.

Contributed by M.M. Killey

While on a drive through central Illinois, you may catch a glimpse of an erratic (photo by J. Dexter).

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PLEISTOCENE GLACIATIONS IN ILLINOIS

Origin of the Glaciers

During the past million years or so, an interval of time called the Pleistocene Epoch, most of the northern hemisphere above the 50th parallel has been repeatedly covered by glacial ice. The cooling of the earth's surface, a prerequisite for glaciation, began at least 2 million years ago. On the basis of evidence found in subpolar oceans of the world (temperature-dependent fossils and oxygen-isotope ratios), a recent proposal has been made to recognize the beginning of the Pleistocene at 1.6 million years ago. Ice sheets formed in sub-arctic regions many times and spread outward until they covered the northern parts of Europe and North America. In North America, early studies of the glacial deposits led to the model that four glaciations could explain the observed distribution of glacial deposits. The deposits of a glaciation were separated from each other by the evidence of intervals of time during which soils formed on the land surface. In order of occurrence from the oldest to the youngest, they were given the names Nebraskan, Kansan, Illinoian, and Wisconsinan Stages of the Pleistocene Epoch. Work in the last 30 years has shown that there were more than four glaciations but the actual number and correlations at this time are not known. Estimates that are gaining credibility suggest that there may have been about 14 glaciations in the last one million years. In Illinois, estimates range from 4 to 8 based on buried soils and glacial deposits. For practical purposes, the previous four glacial stage model is functional, but we now know that the older stages are complex and probably contain more than one glaciation. Until we know more, all of the older glacial deposits, including the Nebraskan and Kansan will be classified as pre-Illinoian. The limits and times of the ice movement in Illinois are illustrated in the following pages by several figures.

The North American ice sheets developed when the mean annual temperature was perhaps 4° to 7°C (7° to 13°F) cooler than it is now and winter snows did not completely melt during the summers. Because the time of cooler conditions lasted tens of thousands of years, thick masses of snow and ice accumulated to form glaciers. As the ice thickened, the great weight of the ice and snow caused them to flow outward at their margins, often for hundreds of miles. As the ice sheets expanded, the areas in which snow accumulated probably also increased in extent.

Tongues of ice, called lobes, flowed southward from the Canadian centers near Hudson Bay and converged in the central lowland between the Appalachian and Rocky Mountains. There the glaciers made their farthest advances to the south. The sketch below shows several centers of flow, the general directions of flow from the centers, and the southern extent of glaciation. Because Illinois lies entirely in the central lowland, it has been invaded by glaciers from every center.

Effects of Glaciation

Pleistocene glaciers and the waters melting from them changed the landscapes they covered. The glaciers scraped and smeared the landforms they overrode, leveling and filling many of the minor valleys and even some of the larger ones. Moving ice carried colossal amounts of rock and earth, for much of what the glaciers wore off the ground was kneaded into the moving ice and carried along, often for hundreds of miles.

The continual floods released by melting ice entrenched new drainageways, deepened old ones, and then partly refilled both with sediments as great quantities of rock and earth were carried beyond the glacier fronts. According to some estimates, the amount of water drawn from the sea and changed into ice during a glaciation was enough to lower the sea level from 300 to 400 feet below present level. Consequently, the melting of a continental ice sheet provided a tremendous volume of water that eroded and transported sediments.

In most of Illinois, then, glacial and meltwater deposits buried the old rock-ribbed, low, hill-and-valley terrain and created the flatter landforms of our prairies. The mantle of soil material and the buried deposits of gravel, sand, and clay left by the glaciers over about 90 percent of the state have been of incalculable value to Illinois residents.

Glacial Deposits

The deposits of earth and rock materials moved by a glacier and deposited in the area once covered by the glacier are collectively called **drift**. Drift that is ice-laid is called **till**. Water-laid drift is called **outwash**.

Till is deposited when a glacier melts and the rock material it carries is dropped. Because this sediment is not moved much by water, a till is unsorted, containing particles of different sizes and compositions. It is also stratified (unlayered). A till may contain materials ranging in size from microscopic clay particles to large boulders. Most tills in Illinois are pebbly clays with only a few boulders. For descriptive purposes, a mixture of clay, silt, sand and boulders is called **diamicton**. This is a term used to describe a deposit that could be interpreted as till or a mass wasting product.

Tills may be deposited as **end moraines**, the arc-shaped ridges that pile up along the glacier edges where the flowing ice is melting as fast as it moves forward. Till also may be deposited as **ground moraines**, or **till plains**, which are gently undulating sheets deposited when the ice front melts back, or retreats. Deposits of till identify areas once covered by glaciers. Northeastern Illinois has many alternating ridges and plains, which are the succession of end moraines and till plains deposited by the Wisconsinan glacier.

Sorted and stratified sediment deposited by water melting from the glacier is called **outwash**. Outwash is bedded, or layered, because the flow of water that deposited it varied in gradient, volume, velocity, and direction. As a meltwater stream washes the rock materials along, it sorts them by size—the fine sands, silts, and clays are carried farther downstream than the coarser gravels and cobbles. Typical Pleistocene outwash in Illinois is in multilayered beds of clays, silts, sands, and gravels that look much like modern stream deposits in some places. In general, outwash tends to be coarser and less weathered, and alluvium is most often finer than medium sand and contains variable amounts of weathered material.

Outwash deposits are found not only in the area covered by the ice field but sometimes far beyond it. Meltwater streams ran off the top of the glacier, in crevices in the ice, and under the ice. In some places, the cobble-gravel-sand filling of the bed of a stream that flowed in the ice is preserved as a sinuous ridge called an **esker**. Some eskers in Illinois are made up of sandy to silty deposits and contain mass wasted diamicton material. Cone-shaped mounds of coarse outwash, called **kames**, were formed where meltwater plunged through crevasses in the ice or into ponds on the glacier.

The finest outwash sediments, the clays and silts, formed bedded deposits in the ponds and lakes that filled glacier-dammed stream valleys, the sags of the till plains, and some low, moraine-diked till plains. Meltwater streams that entered a lake rapidly lost speed and also quickly dropped the sands and gravels they carried, forming deltas at the edge of the lake. Very fine sand and silts were commonly redistributed on the lake bottom by wind-generated currents, and the clays, which stayed in suspension longest, slowly settled out and accumulated with them.

Along the ice front, meltwater ran off in innumerable shifting and short-lived streams that laid down a broad, flat blanket of outwash that formed an **outwash plain**. Outwash was also carried away from the glacier in valleys cut by floods of meltwater. The Mississiippi, Illinois, and Ohio Rivers occupy valleys that were major channels for meltwaters and were greatly widened and deepened during times of the greatest meltwater floods. When the floods waned, these valleys were partly filled with outwash far beyond the ice margins. Such outwash deposits, largely sand and gravel, are known as **valley trains**. Valley train deposits may be both extensive and thick. For instance, the long valley train of the Mississippi Valley is locally as much as 200 feet thick.

Loess, Eolian Sand and Soils

One of the most widespread sediments resulting from glaciation was carried not by ice or water but by wind. **Loess** is the name given to windblown deposits dominated by silt. Most of the silt was derived from wind erosion of the valley trains. Wind action also sorted out **eolian sand** which commonly formed **sand dunes** on the valley trains or on the adjacent uplands. In places, sand dunes have migrated up to 10 miles away from the principle source of sand. Flat areas between dunes are generally underlain by eolian **sheet sand** that is commonly reworked by water action. On uplands along the major valley trains, loess and eolian sand are commonly interbedded. With increasing distance from the valleys, the eolian sand pinches out, often within one mile.

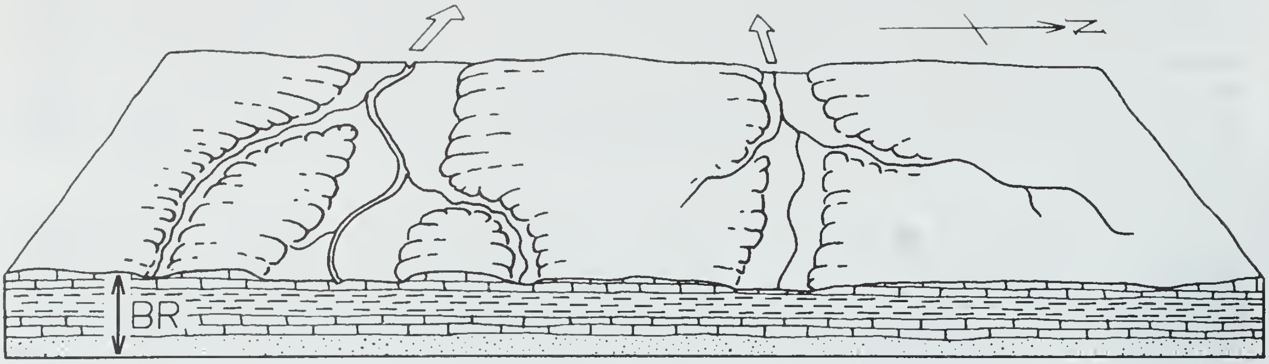
Eolian deposition occurred when certain climatic conditions were met, probably in a seasonal pattern. Deposition could have occurred in the fall, winter or spring season when low precipitation rates and low temperatures caused meltwater floods to abate, exposing the surfaces of the valley trains and permitting them to dry out. During Pleistocene time, as now, west winds prevailed, and the loess deposits are thickest on the east sides of the source valleys. The loess thins rapidly away from the valleys but extends over almost all the state.

Each Pleistocene glaciation was followed by an interglacial stage that began when the climate warmed enough to melt the glaciers and their snowfields. During these warmer intervals, when the climate was similar to that of today, drift and loess surfaces were exposed to weather and the activities of living things. Consequently, over most of the glaciated terrain, soils developed on the Pleistocene deposits and altered their composition, color, and texture. Such soils were generally destroyed by later glacial advances, but some were buried. Those that survive serve as "key beds," or stratigraphic markers, and are evidence of the passage of a long interval of time.

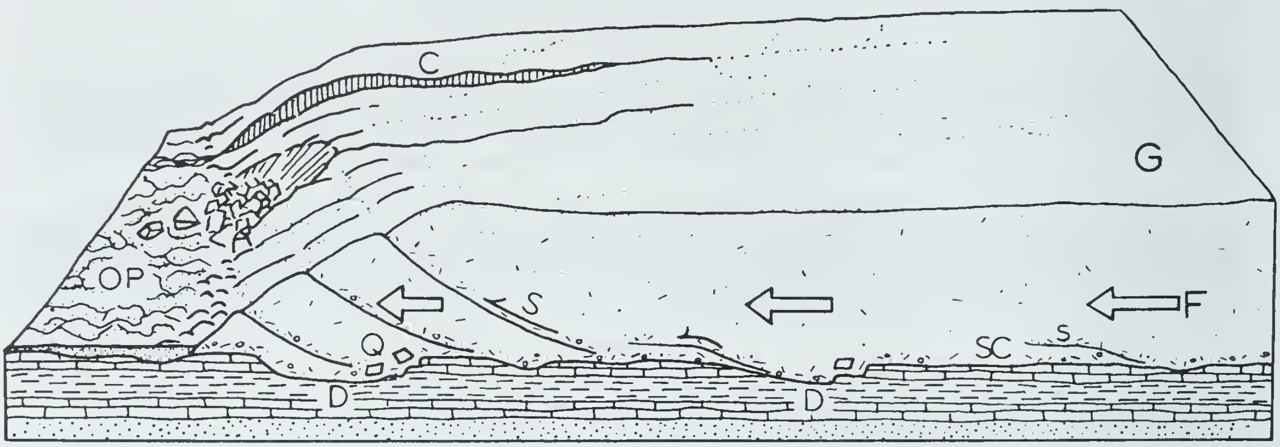
Glaciation in a Small Illinois Region

The following diagrams show how a continental ice sheet might have looked at various stages as it moved across a small region in Illinois. They illustrate how it could change the old terrain and create a landscape like the one we live on. To visualize how these glaciers looked, geologists study the landforms and materials left in the glaciated regions and also the present-day mountain glaciers and polar ice caps.

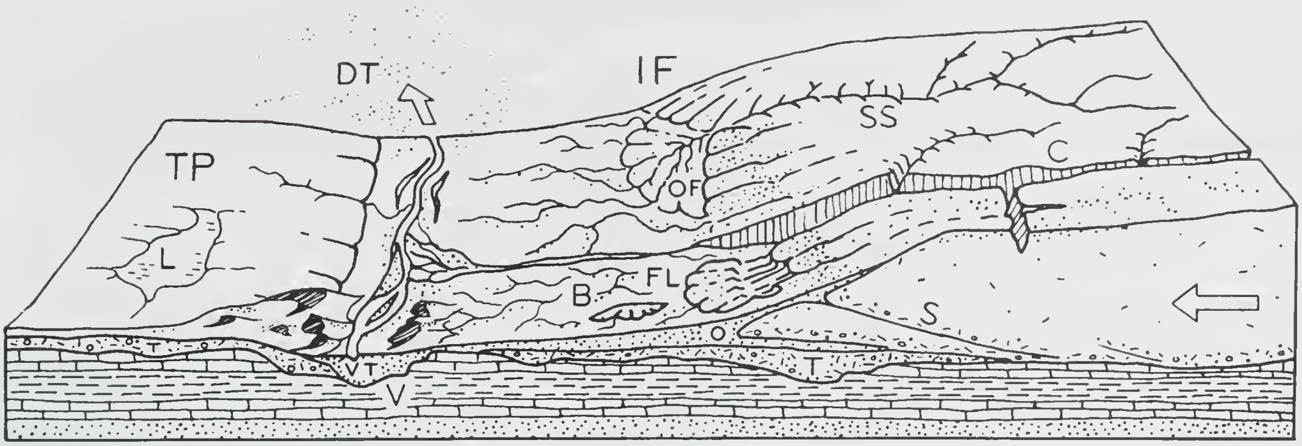
The block of land in the diagrams is several miles wide and about 10 miles long. The vertical scale is exaggerated—layers of material are drawn thicker and landforms higher than they ought to be so that they can be easily seen.



1. **The Region Before Glaciation** — Like most of Illinois, the region illustrated is underlain by almost flat-lying beds of sedimentary rocks—layers of sandstone ( ), limestone ( ), and shale ( ). Millions of years of erosion have planed down the bedrock (BR), creating a terrain of low uplands and shallow valleys. A residual soil weathered from local rock debris covers the area but is too thin to be shown in the drawing. The streams illustrated here flow westward and the one on the right flows into the other at a point beyond the diagram.



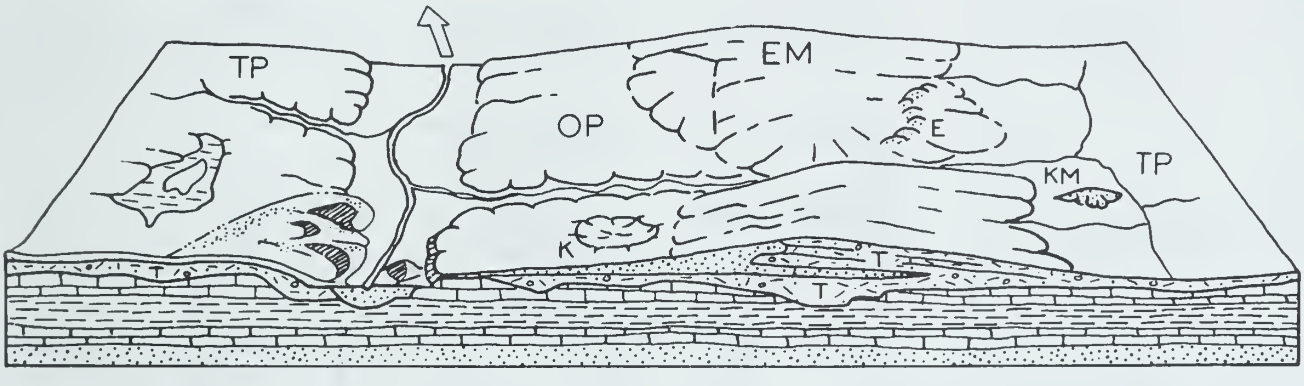
2. **The Glacier Advances Southward** — As the Glacier (G) spreads out from its ice snowfield accumulation center, it scours (SC) the soil and rock surface and quarries (Q)—pushes and plucks up—chunks of bedrock. The materials are mixed into the ice and make up the glacier's "load." Where roughnesses in the terrain slow or stop flow (F), the ice "current" slides up over the blocked ice on innumerable shear planes (S). Shearing mixes the load very thoroughly. As the glacier spreads, long cracks called "crevasses" (C) open parallel to the direction of ice flow. The glacier melts as it flows forward, and its meltwater erodes the terrain in front of the ice, deepening (D) some old valleys before ice covers them. Meltwater washes away some of the load freed by melting and deposits it on the outwash plain (OP). The advancing glacier overrides its outwash and in places scours much of it up again. The glacier may be 5000 or so feet thick, and tapers to the margin, which was probably in the range of several hundred feet above the old terrain. The ice front advances perhaps as much as a third of a mile per year.



3. **The Glacier Deposits an End Moraine** — After the glacier advances across the area, the climate warms and the ice begins to melt as fast as it advances. The ice front (IF) is now stationary, or fluctuating in a narrow area, and the glacier is depositing an end moraine.

As the top of the glacier melts, some of the sediment that is mixed in the ice accumulates on top of the glacier. Some is carried by meltwater onto the sloping ice front (IF) and out onto the plain beyond. Some of the debris slips down the ice front in a mudflow (FL). Meltwater runs through the ice in a crevasse (C). A supraglacial stream (SS) drains the top of the ice, forming an outwash fan (OF). Moving ice has overridden an immobile part of the front on a shear plane (S). All but the top of a block of ice (B) is buried by outwash (O).

Sediment from the melted ice of the previous advance (figure 2) remains as a till layer (T), part of which forms the till plain (TP). A shallow, marshy lake (L) fills a low place in the plain. Although largely filled with drift, the valley (V) remains a low spot in the terrain. As soon as the ice cover melts, meltwater drains down the valley, cutting it deeper. Later, outwash partly refills the valley: the outwash deposit is called a valley train (VT). Wind blows dust (DT) off the dry floodplain. The dust will form a loess deposit when it settles. Sand dunes (D) form on the south and east sides of streams.



4. **The Region after Glaciation** — As the climate warms further, the whole ice sheet melts, and glaciation ends. The end moraine (EM) is a low, broad ridge between the outwash plain (OP) and till plains (TP). Run-off from rains cuts stream valleys into its slopes. A stream goes through the end moraine along the channel cut by the meltwater that ran out of the crevasse in the glacier.

Slopewash and vegetation are filling the shallow lake. The collapse of outwash into the cavity left by the ice block's melting has made a kettle (K). The outwash that filled a tunnel draining under the glacier is preserved in an esker (E). The hill of outwash left where meltwater dumped sand and gravel into a crevasse or other depression in the glacier or at its edge is a kame (KM). A few feet of loess covers the entire area but cannot be shown at this scale.

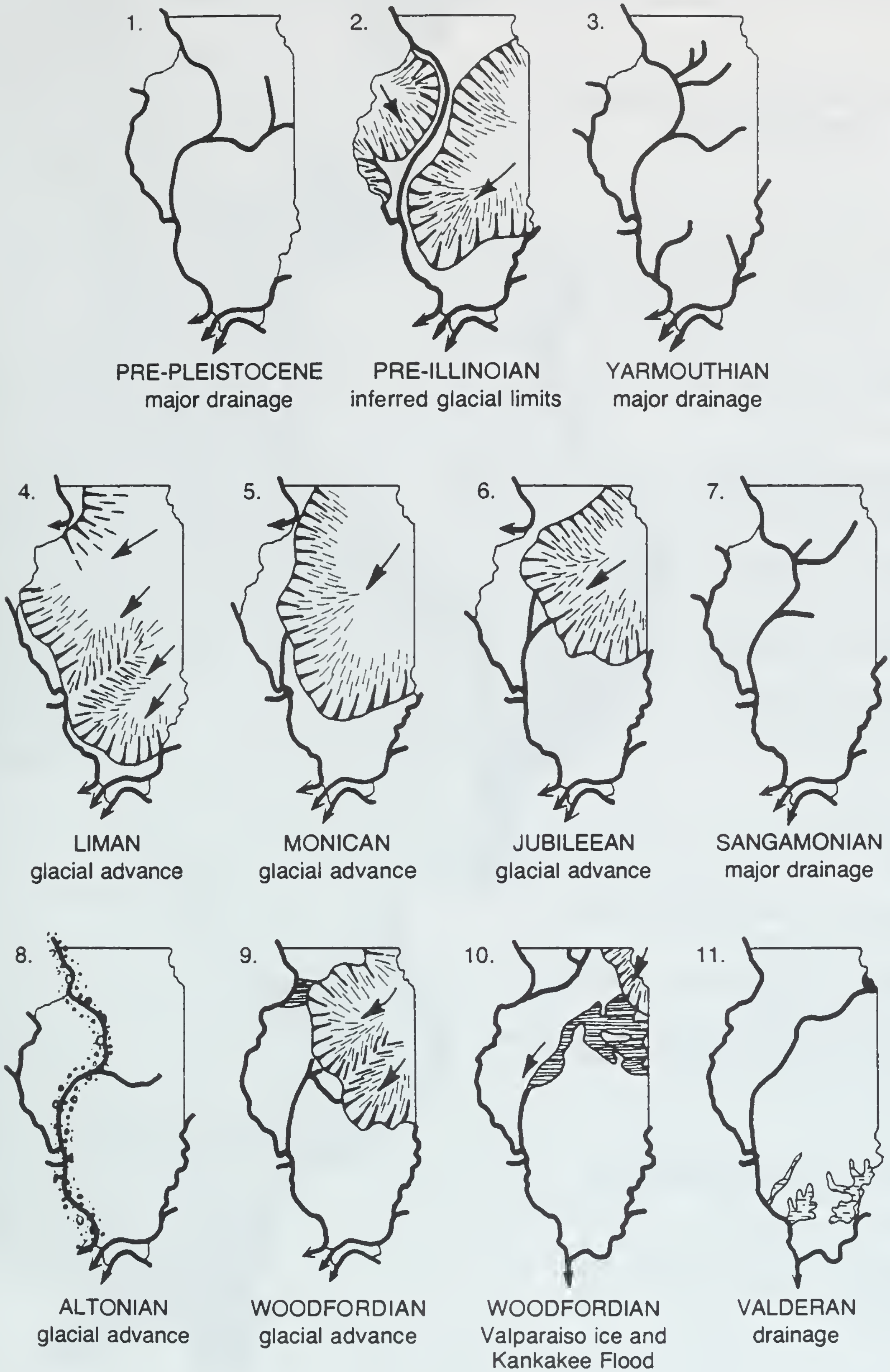
TIME TABLE OF PLEISTOCENE GLACIATION

		STAGE		SUBSTAGE	NATURE OF DEPOSITS	SPECIAL FEATURES
QUATERNARY		HOLOCENE (interglacial)		Years Before Present	Soil, youthful profile of weathering, lake and river deposits, dunes, peat	
				10,000		
	Pleistocene	WISCONSINAN (glacial)	late	Valderan	Outwash, lake deposits	Outwash along Mississippi Valley
				11,000		
			late	Twocreekan	Peat and alluvium	Ice withdrawal, erosion
				12,500		
			late	Woodfordian	Drift, loess, dunes, lake deposits	Glaciation; building of many moraines as far south as Shelbyville; extensive valley trains, outwash plains, and lakes
				25,000		
			mid	Farmdalian	Soil, silt, and peat	Ice withdrawal, weathering, and erosion
				28,000		
			early	Altonian	Drift, loess	Glaciation in Great Lakes area, valley trains along major rivers
				75,000		
		SANGAMONIAN (interglacial)			Soil, mature profile of weathering	Important stratigraphic marker
				125,000		
		ILLINOIAN (glacial)		Jubileean	Drift, loess, outwash	Glaciers from northeast at maximum reached Mississippi River and nearly to southern tip of Illinois
				Monican	Drift, loess, outwash	
				Liman	Drift, loess, outwash	
				300,000?		
		YARMOUTHIAN (interglacial)			Soil, mature profile of weathering	Important stratigraphic marker
				500,000?		
	Pre-Illinoian	KANSAN* (glacial)			Drift, loess	Glaciers from northeast and northwest covered much of state
				700,000?		
		AFTONIAN* (interglacial)			Soil, mature profile of weathering	(hypothetical)
				900,000?		
		NEBRASKAN* (glacial)			Drift (little known)	Glaciers from northwest invaded western Illinois
				1,600,000 or more		

*Old oversimplified concepts, now known to represent a series of glacial cycles.

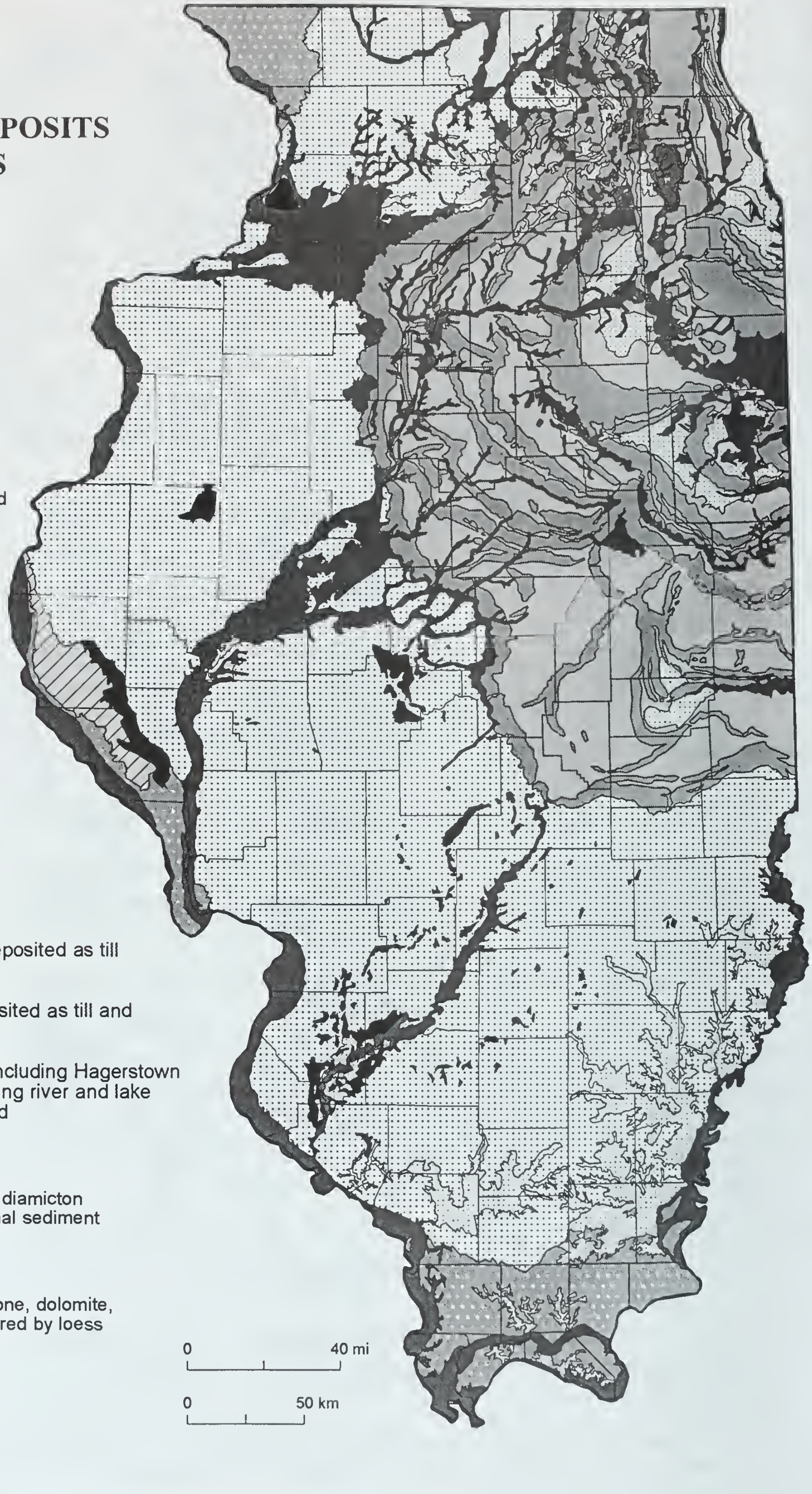
(Illinois State Geological Survey, 1973)

SEQUENCE OF GLACIATIONS AND INTERGLACIAL
DRAINAGE IN ILLINOIS



(Modified from Willman and Frye, "Pleistocene Stratigraphy of Illinois," ISGS Bull. 94, fig. 5, 1970.)

QUATERNARY DEPOSITS OF ILLINOIS



Hudson and Wisconsin Episodes

Mason Group and Cahokia Fm

Cahokia and Henry Fms; sorted sediment including waterlain river sediment and windblown and beach sand

Equality Fm; fine grained sediment deposited in lakes

—5— Thickness of Peoria and Roxana Silts; silt deposited as loess (5 ft contour interval)

Wedron Group (Tiskilwa, Lemont, and Wadsworth Fms) and Trafalgar Fm; diamicton deposited as till and ice-marginal sediment

End moraine

Ground moraine

Illinois Episode

Winnebago Fm; diamicton deposited as till and ice-marginal sediment

Glasford Fm; diamicton deposited as till and ice-marginal sediment

Teneriffe Silt and Pearl Fm, including Hagerstown Mbr; sorted sediments including river and lake deposits and wind blown sand

Pre-Illinois Episodes

Wolf Creek Fm; predominantly diamicton deposited as till and ice-marginal sediment

Paloezoic, Mesozoic, and Cenozoic

Mostly Paleozoic shale, limestone, dolomite, or sandstone; exposed or covered by loess and/or residuum

ILLINOIS STATE GEOLOGICAL SURVEY
Urbana, Illinois 61801

GEOGRAM 5
October 1975

ANCIENT DUST STORMS IN ILLINOIS

Myrna M. Killey

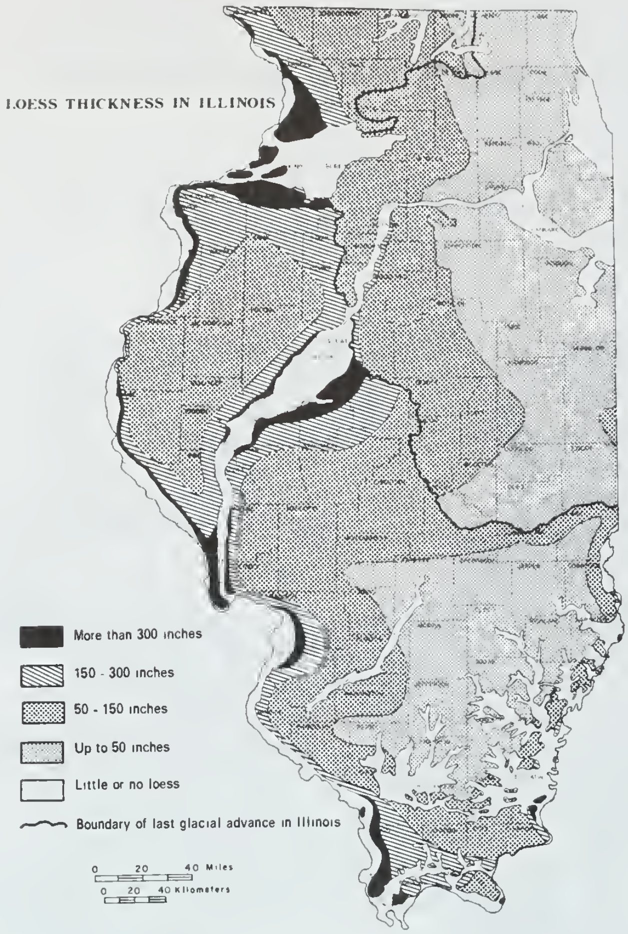
Fierce dust storms whirled across Illinois long before human beings were here to record them. Where did all the dust come from? Geologists have carefully put together clues from the earth itself to get the story. As the glaciers of the Great Ice Age scraped and scoured their way southward across the landscape from Canada, they moved colossal amounts of rock and earth. Much of the rock ground from the surface was kneaded into the ice and carried along, often for hundreds of miles. The glaciers acted as giant grist mills, grinding much of the rock and earth to "flour"—very fine dust-sized particles.

During the warm seasons, water from the melting ice poured from the glacier front, laden with this rock flour, called silt. In the cold months the meltwater stopped flowing and the silt was left along the channels the water had followed, where it dried out and became dust. Strong winds picked up the dust, swept it from the floodplains, and carried it to adjacent uplands. There the forests along the river valleys trapped the dust, which became part of the moist forest soil. With each storm more material accumulated until the high bluffs adjacent to major rivers were formed. The dust deposits are thicker along the eastern sides of the valleys than they are on the western sides, a fact from which geologists deduce that the prevailing winds of that time blew from west to east, the same direction as those of today. From such clues geologists conclude that the geologic processes of the past were much like those of today.

The deposits of windblown silt are called loess (rhymes with "bus"). Loess is found not only in the areas once covered by the glaciers but has been blown into the nonglaciated areas. The glaciers, therefore, influenced the present land surface well beyond the line of their farthest advance.

Loess has several interesting characteristics. Its texture is so fine and uniform that it can easily be identified in roadcuts—and because it blankets such a vast area many roads are cut through it. Even more noticeable is its tendency to stand in vertical walls. These steep walls develop as the loess drains and becomes tough, compact, and massive, much like a rock. Sometimes cracks develop in the loess, just as they do in massive limestones and sandstones. Loess makes good highway banks if it is cut vertically. A vertical cut permits maximum drainage because little surface is exposed to rain, and rainwater tends to drain straight down through it to the rock underneath. If the bank is cut at an angle more water soaks in, which causes the loess to slump down. Along Illinois roads the difference between a loess roadcut and one in ordinary glacial till is obvious. The loess has a very uniform texture, while the till is composed of a random mixture of rock debris, from clay and silt through cobbles and boulders.

Many loess deposits are worth a close look. Through a 10-power hand lens separate grains can be seen, among them many clear, glassy, quartz grains. Some loess deposits contain numerous rounded, lumpy stones called concretions. Their formation began when water percolating through the loess dissolved tiny



limestone grains. Some of the dissolved minerals later became solid again, gathering around a tiny nucleus or along roots to form the lumpy masses. A few such concretions are shaped roughly like small dolls and, from this resemblance, are called "loess kindchen," a German term meaning "loess children." They may be partly hollow and contain smaller lumps that make them rattle when shaken.

Fossil snails can be found in some loess deposits. The snails lived on the river bluffs while the loess was being deposited and were buried by the dust. When they are abundant, they are used to determine how old the loess is. The age is found by measuring the amount of radioactive carbon in the calcium carbonate of their shells.

Some of the early loess deposits were covered by new layers of loess following later glacial invasions. Many thousands of years passed between the major glacial periods, during which time the climate was as warm as that of today. During the warm intervals, the surface of the loess and other glacial deposits was exposed to weather. Soils developed on most of the terrain, altering the composition, color, and texture of the glacial material. During later advances of the ice, some of these soils were destroyed, but in many places they are preserved under the younger sediments. Such ancient buried soils can be used to determine when the materials above and below them were laid down by the ice and what changes in climate took place.

The blanket of loess deposited by the ancient dust storms forms the parent material of the rich, deep soils that today are basic to the state's agriculture. A soil made of loess crumbles easily and has great moisture-holding capacity. It also is free from rocks that might complicate cultivation. Those great dust storms that swirled over the land many thousands of years ago thus endowed Illinois with one of its greatest resources, its highly productive soil.

DEPOSITIONAL HISTORY OF THE PENNSYLVANIAN ROCKS IN ILLINOIS

At the close of the Mississippian Period, about 310 million years ago, the sea withdrew from the Midcontinent region. A long interval of erosion that took place early in Pennsylvanian time removed hundreds of feet of the pre-Pennsylvanian strata, completely stripping them away and cutting into older rocks over large areas of the Midwest. Ancient river systems cut deep channels into the bedrock surface. Later, but still during early Pennsylvanian (Morrowan) time, the sea level started to rise; the corresponding rise in the base level of deposition interrupted the erosion and led to filling the valleys in the erosion surface with fluvial, brackish, and marine sands and muds.

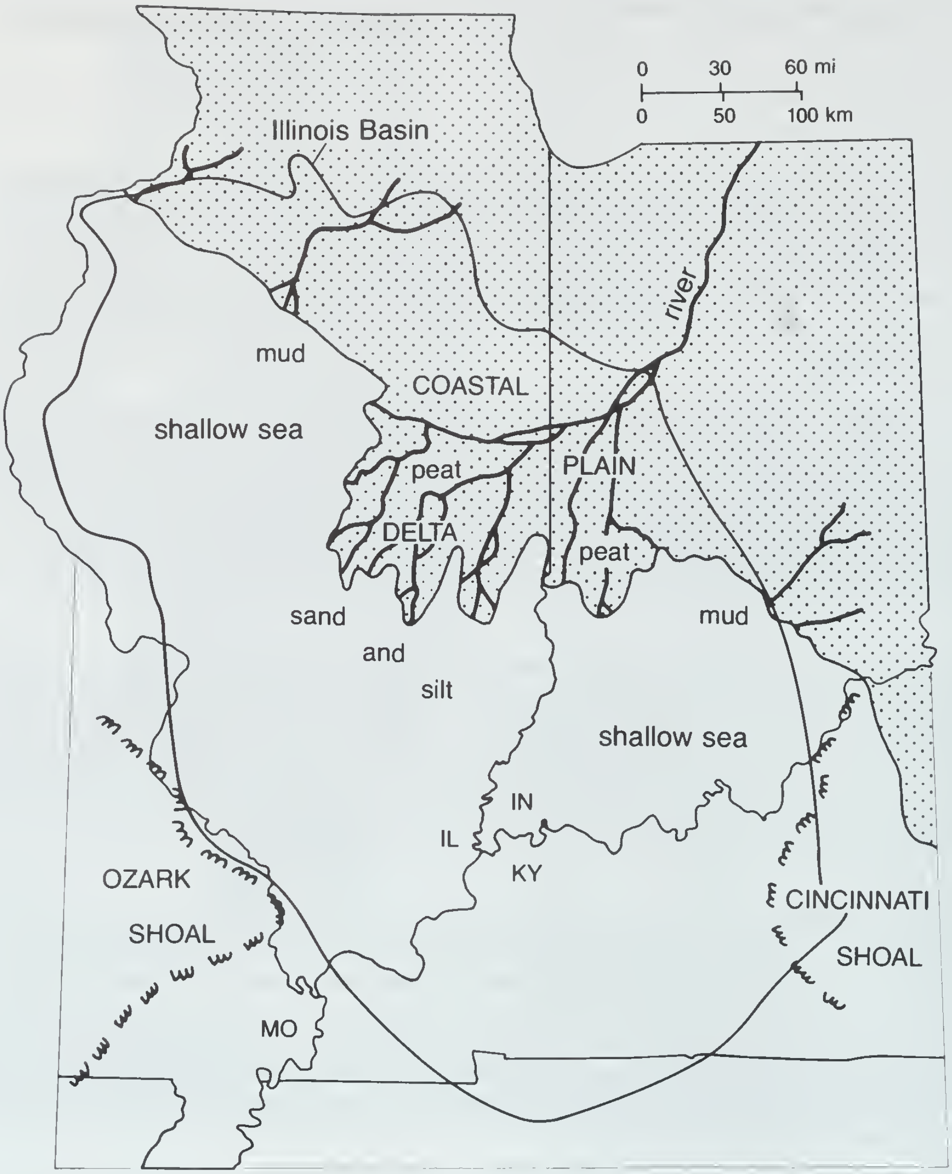
Depositional conditions in the Illinois Basin during the Pennsylvanian Period were somewhat similar to those of the preceding Chesterian (late Mississippian) time. A river system flowed southwestward across a swampy lowland, carrying mud and sand from highlands to the northeast. This river system formed thin but widespread deltas that coalesced into a vast coastal plain or lowland that prograded (built out) into the shallow sea that covered much of present-day Illinois (see paleogeographic map, next page). As the lowland stood only a few feet above sea level, slight changes in relative sea level caused great shifts in the position of the shoreline.

During most of Pennsylvanian time, the Illinois Basin gradually subsided; a maximum of about 3000 feet of Pennsylvanian sediments are preserved in the basin. The locations of the delta systems and the shoreline of the resulting coastal plain shifted, probably because of worldwide sea level changes, coupled with variation in the amounts of sediments provided by the river system and local changes in basin subsidence rates. These frequent shifts in the coastline position caused the depositional conditions at any one locality in the basin to alternate frequently between marine and nonmarine, producing a variety of lithologies in the Pennsylvanian rocks (see lithology distribution chart).

Conditions at various places on the shallow sea floor favored the deposition of sand, lime mud, or mud. Sand was deposited near the mouths of distributary channels, where it was reworked by waves and spread out as thin sheets near the shore. Mud was deposited in quiet-water areas — in delta bays between distributaries, in lagoons behind barrier bars, and in deeper water beyond the nearshore zone of sand deposition. Limestone was formed from the accumulation of limy parts of plants and animals laid down in areas where only minor amounts of sand and mud were being deposited. The areas of sand, mud, and limy mud deposition continually changed as the position of the shoreline changed and as the delta distributaries extended seaward or shifted their positions laterally along the shore.

Nonmarine sand, mud, and lime mud were deposited on the coastal plain bordering the sea. The nonmarine sand was deposited in delta distributary channels, in river channels, and on the broad floodplains of the rivers. Some sand bodies 100 or more feet thick were deposited in channels that cut through the underlying rock units. Mud was deposited mainly on floodplains. Some mud and freshwater lime mud were deposited locally in fresh-water lakes and swamps.

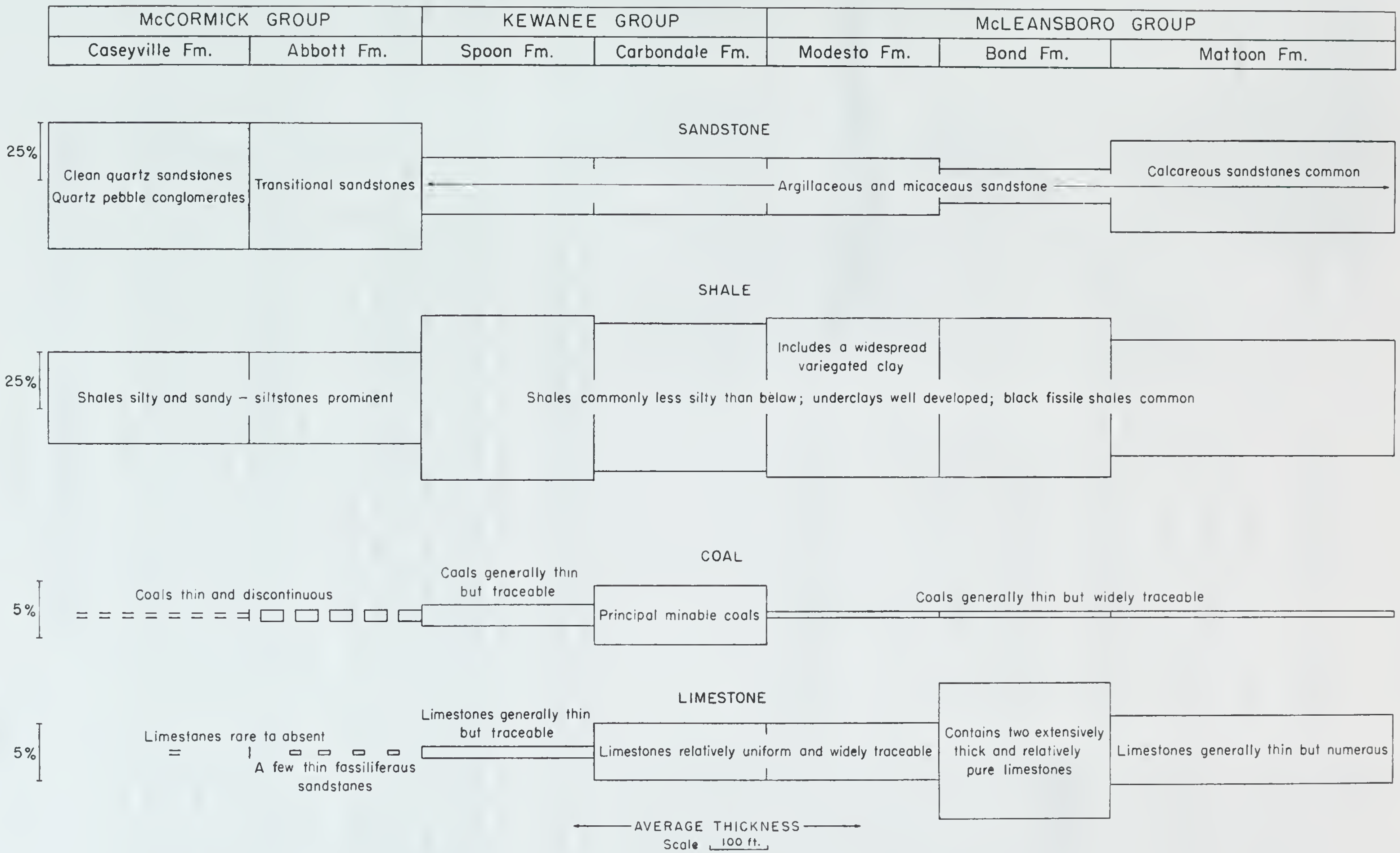
Beneath the quiet water of extensive swamps that prevailed for long intervals on the emergent coastal lowland, peat was formed by accumulation of plant material. Lush forest vegetation covered the region; it thrived in the warm, moist Pennsylvanian-age climate. Although the origin of the underclays beneath the coal is not precisely known, most evidence indicates that they were deposited in the swamps as slackwater mud before the accumulation of much plant debris. The clay underwent modification to become the soil upon which the lush vegetation grew in the swamps. Underclay frequently contains plant roots and rootlets that appear to be in their original places. The vast swamps were the culmination of nonmarine deposition. Resubmergence of the borderlands by the sea interrupted nonmarine deposition, and marine sediments were laid down over the peat.



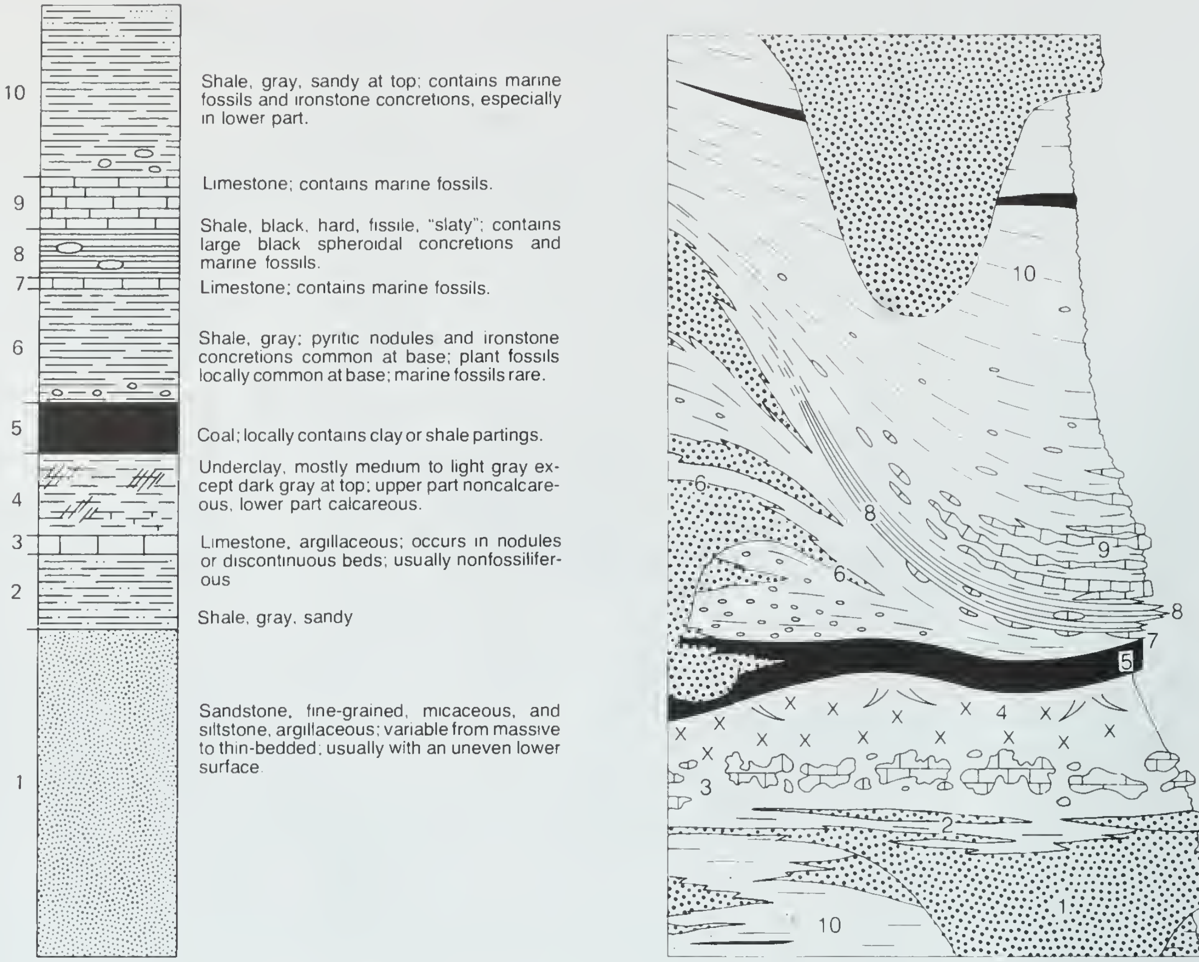
Paleogeography of Illinois-Indiana region during Pennsylvanian time. The diagram shows a Pennsylvanian river delta and the position of the shoreline and the sea at an instant of time during the Pennsylvanian Period.

Pennsylvanian Cyclothems

The Pennsylvanian strata exhibit extraordinary variations in thickness and composition both laterally and vertically because of the extremely varied environmental conditions under which they formed. Individual sedimentary units are often only a few inches thick and rarely exceed 30 feet thick. Sandstones and shales commonly grade laterally into each other, and shales sometimes interfinger and grade into limestones and coals. The underclays, coals, black shales, and some limestones, however, display remarkable lateral continuity for such thin units. Coal seams have been traced in mines, outcrops, and subsurface drill records over areas comprising several states.



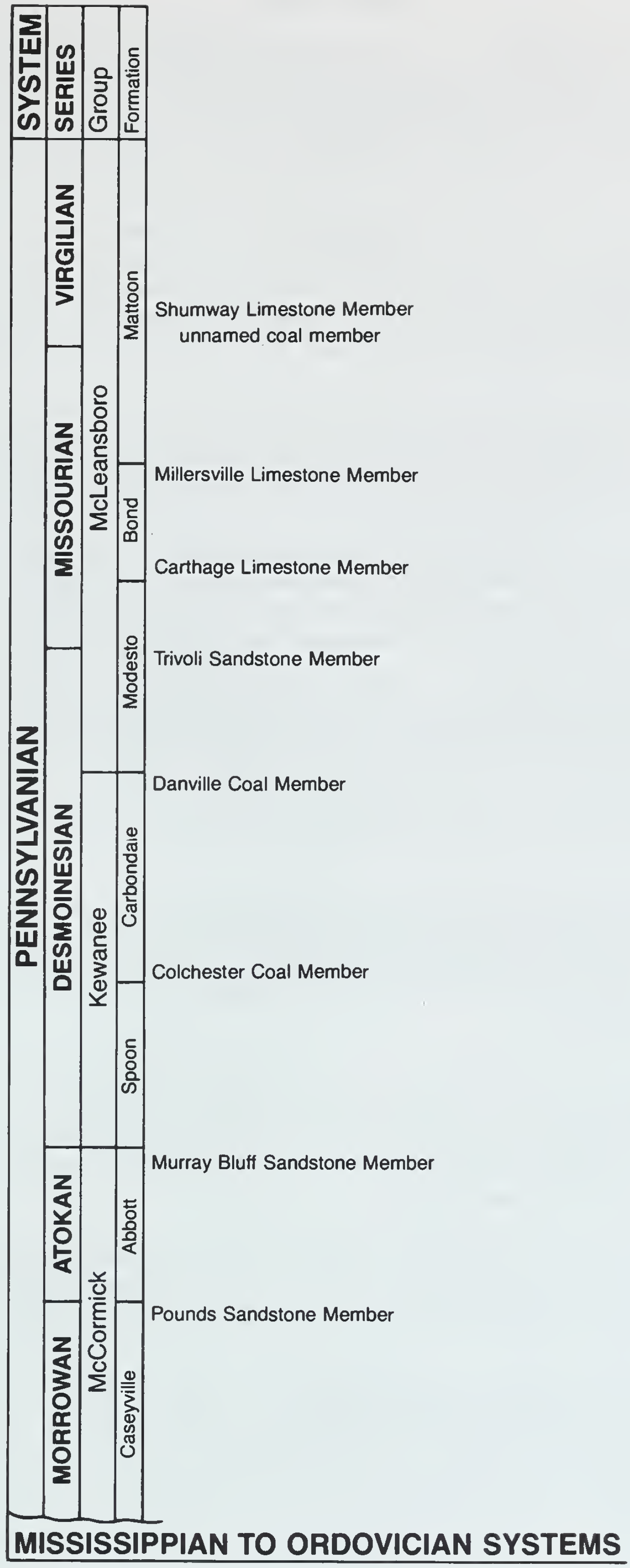
General distribution of the four principal lithologies in Pennsylvanian strata of Illinois.



The idealized cyclothem at left (after Willman and Payne, 1942) infers continuous, widespread distribution of individual cyclothem units, at right the model of a typical cyclothem (after Baird and Shabica, 1980) shows the discontinuous nature of many units in a cyclothem.

The rapid and frequent changes in depositional environments during Pennsylvanian time produced regular or cyclical alternations of sandstone, shale, limestone, and coal in response to the shifting shoreline. Each series of alternations, called a cyclothem, consists of several marine and nonmarine rock units that record a complete cycle of marine invasion and retreat. Geologists have determined, after extensive studies of the Pennsylvanian strata in the Midwest, that an "ideally" complete cyclothem consists of ten sedimentary units (see illustration above contrasting the model of an "ideal" cyclothem with a model showing the dynamic relationships between the various members of a typical cyclothem).

Approximately 50 cyclothems have been described in the Illinois Basin but only a few contain all ten units at any given location. Usually one or more are missing because conditions of deposition were more varied than indicated by the "ideal" cyclothem. However, the order of units in each cyclothem is almost always the same: a typical cyclothem includes a basal sandstone overlain by an underclay, coal, black sheety shale, marine limestone, and gray marine shale. In general, the sandstone-underclay-coal-gray shale portion (the lower six units) of each cyclothem is nonmarine: it was deposited as part of the coastal lowlands from which the sea had withdrawn. However, some of the sandstones are entirely or partly marine. The units above the coal and gray shale are marine sediments deposited when the sea advanced over the coastal plain.



Generalized stratigraphic column of the Pennsylvanian in Illinois (1 inch = approximately 250 feet).

Origin of Coal

It is generally accepted that the Pennsylvanian coals originated by the accumulation of vegetable matter, usually in place, beneath the waters of extensive, shallow, fresh-to-brackish swamps. They represent the last-formed deposits of the nonmarine portions of the cyclothems. The swamps occupied vast areas of the coastal lowland, which bordered the shallow Pennsylvanian sea. A luxuriant growth of forest plants, many quite different from the plants of today, flourished in the warm, humid Pennsylvanian climate. (Illinois at that time was near the equator.) The deciduous trees and flowering plants that are common today had not yet evolved. Instead, the jungle-like forests were dominated by giant ancestors of present-day club mosses, horsetails, ferns, conifers, and cycads. The undergrowth also was well developed, consisting of many ferns, fernlike plants, and small club mosses. Most of the plant fossils found in the coals and associated sedimentary rocks show no annual growth rings, suggesting rapid growth rates and lack of seasonal variations in the climate (tropical). Many of the Pennsylvanian plants, such as the seed ferns, eventually became extinct.

Plant debris from the rapidly growing swamp forests — leaves, twigs, branches, and logs — accumulated as thick mats of peat on the floors of the swamps. Normally, vegetable matter rapidly decays by oxidation, forming water, nitrogen, and carbon dioxide. However, the cover of swamp water, which was probably stagnant and low in oxygen, prevented oxidation, and any decay of the peat deposits was due primarily to bacterial action.

The periodic invasions of the Pennsylvanian sea across the coastal swamps killed the Pennsylvanian forests, and the peat deposits were often buried by marine sediments. After the marine transgressions, peat usually became saturated with sea water containing sulfates and other dissolved minerals. Even the marine sediments being deposited on the top of the drowned peat contained various minerals in solution, including sulfur, which further infiltrated the peat. As a result, the peat developed into a coal that is high in sulfur. However, in a number of areas, nonmarine muds, silts, and sands from the river system on the coastal plain covered the peat where flooding broke through levees or the river changed its coarse. Where these sediments (unit 6 of the cyclothem) are more than 20 feet thick, we find that the coal is low in sulfur, whereas coal found directly beneath marine rocks is high in sulfur. Although the seas did cover the areas where these nonmarine, fluvial sediments covered the peat, the peat was protected from sulfur infiltration by the shielding effect of these thick fluvial sediments.

Following burial, the peat deposits were gradually transformed into coal by slow physical and chemical changes in which pressure (compaction by the enormous weight of overlying sedimentary layers), heat (also due to deep burial), and time were the most important factors. Water and volatile substances (nitrogen, hydrogen, and oxygen) were slowly driven off during the coal-forming ("coalification") process, and the peat deposits were changed into coal.

Coals have been classified by ranks that are based on the degree of coalification. The commonly recognized coals, in order of increasing rank, are (1) brown coal or lignite, (2) sub-bituminous, (3) bituminous, (4) semibituminous, (5) semianthracite, and (6) anthracite. Each increase in rank is characterized by larger amounts of fixed carbon and smaller amounts of oxygen and other volatiles. Hardness of coal also increases with increasing rank. All Illinois coals are classified as bituminous.

Underclays occur beneath most of the coals in Illinois. Because underclays are generally unstratified (unlayered), are leached to a bleached appearance, and generally contain plant roots, many geologists consider that they represent the ancient soils on which the coal-forming plants grew.

The exact origin of the carbonaceous black shale that occurs above many coals is uncertain. Current thinking suggests that the black shale actually represents the deepest part of the marine transgression. Maximum transgression of the sea, coupled with upwelling of ocean water and accumulation of mud and animal remains on an anaerobic ocean floor, led to the deposition of black organic mud over vast areas stretching from Texas to Illinois. Deposition occurred in quiet-water areas where the very fine-grained iron-rich

mud and finely divided plant debris were washed in from the land. Most of the fossils found in black shale represent planktonic (floating) and nektonic (swimming) forms — not benthonic (bottom-dwelling) forms. The depauperate (dwarf) fossil forms sometimes found in black shale formerly were thought to have been forms that were stunted by toxic conditions in the sulfide-rich, oxygen-deficient water of the lagoons. However, study has shown that the "depauperate" fauna consists mostly of normal-size individuals of species that never grew any larger.

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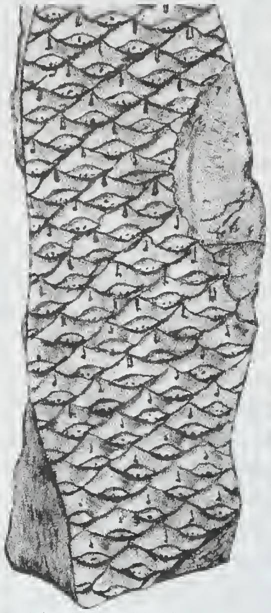
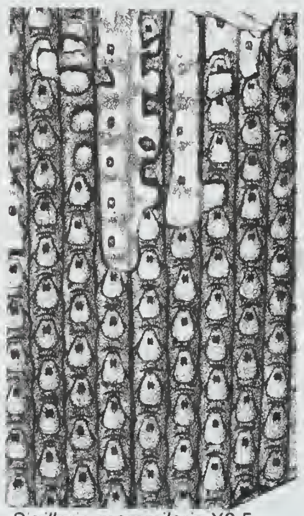
Common Pennsylvanian plants: lycopods, sphenophytes, and ferns

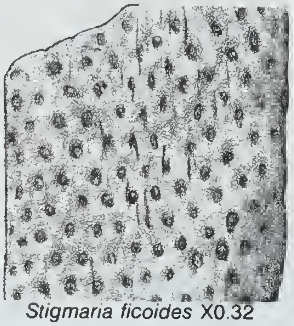
Lepidodendron aculeatum X0.8



Lepidophloios laricinus X0.63

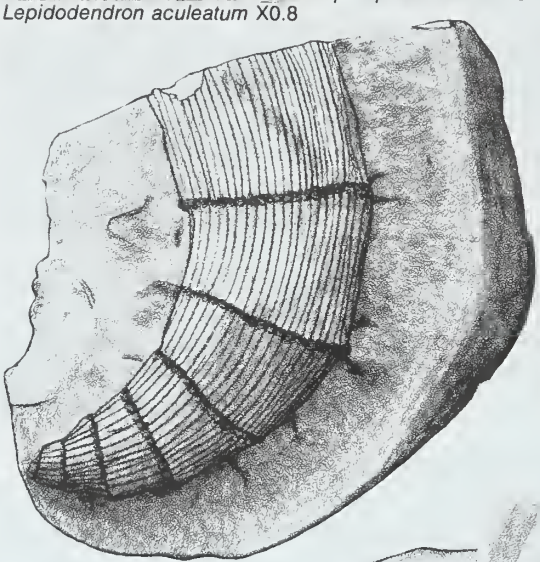


Sigillaria mammilaris X0.5



Stigmaria ficoides X0.32

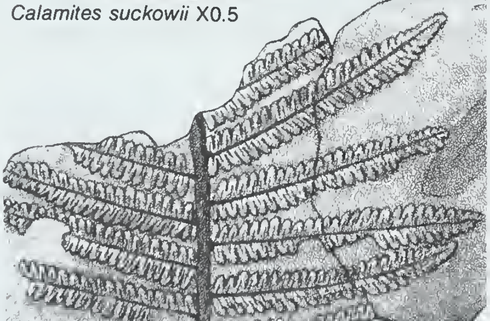
Lepidostrobus ovatifolius X0.8



Calamites suckowii X0.5

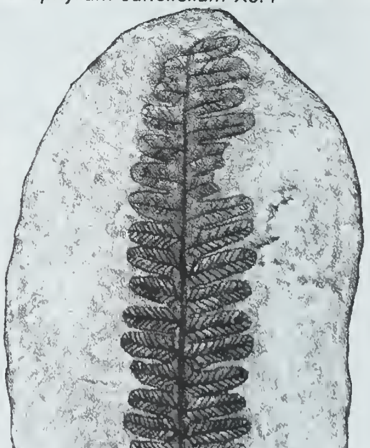
Annularia stellata X0.63

Sphenophyllum cuneifolium X0.4



Pecopteris sp. X0.32

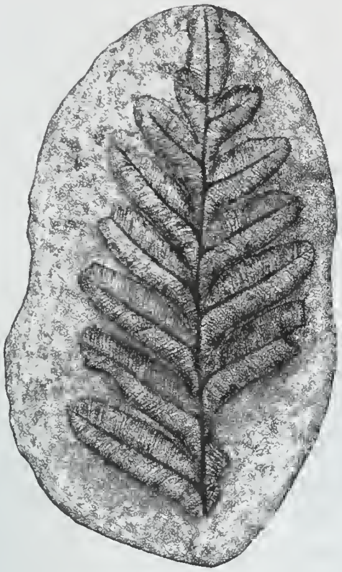
Pecopteris miltonii X2.0



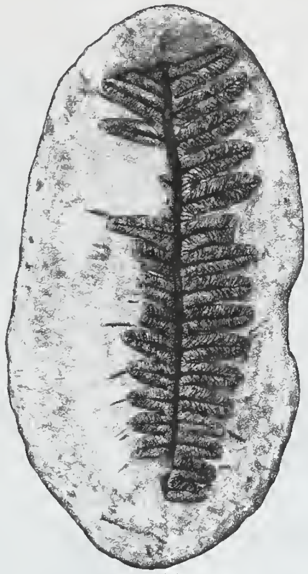
Pecopteris hemitelioides X1.0

J. R. Jennings, ISGS

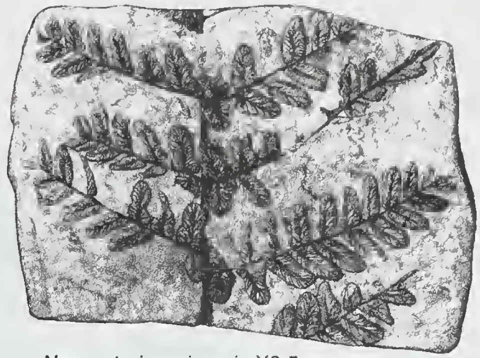
Common Pennsylvanian plants: seed ferns and cordaiteans



Alethopteris serlii X0.63



Alethopteris ambigua X0.63



Neuropteris rarinervis X0.5

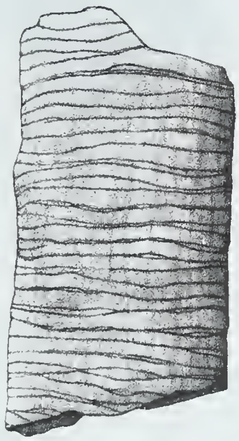
Mariopteris nervosa X0.8

Neuropteris scheuchzeri X0.63

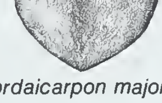
Sphenopteris rotundiloba X0.8

Trigonocarpus parkinsonii X1.25

Cordaicladus sp. X1.0



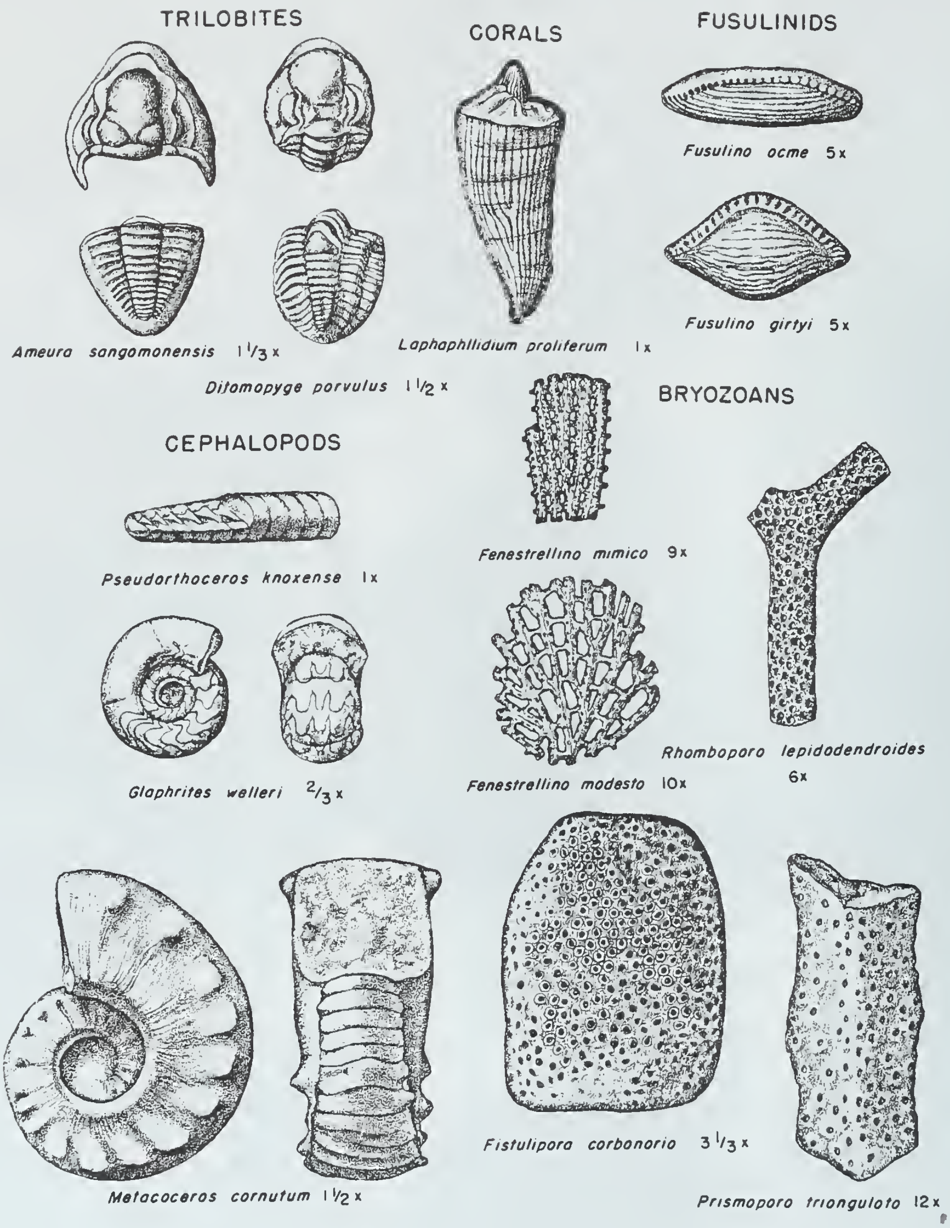
Artisia transversa X0.63



Cordaicarpon major X2.0

Cordaites principalis X0.63

J. R. Jennings, ISGS


TRILOBITES
CORALS
FUSULINIDS
Fusulina acme 5x
Fusulina girtyi 5x
Ameura sangamonensis $1\frac{1}{3}$x
Lophophyllidium proliferum 1x
Ditomopyge parvulus $1\frac{1}{2}$x
BRYOZOANS
CEPHALOPODS
Pseudorthoceros knoxense 1x
Fenestrellina mimica 9x
Glaphrites welleri $\frac{2}{3}$x
Fenestrellina modesta 10x
Rhombopora lepidodendroides 6x
Fistulipora carbonaria $3\frac{1}{3}$x
Metacoceras cornutum $1\frac{1}{2}$x
Prismopora triangulata 12x

PELECYPODS

Nucula (Nuculopsis) girtyi 1x

Edmondia ovata 2x

Astartella concentrica 1x

Dunbarella knighti 1½x

Cardiomorpha missouriensis "Type A" 1x

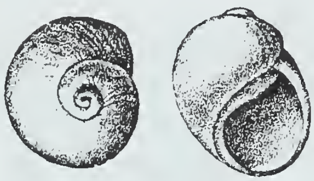
Cardiomorpha missouriensis "Type B" 1½x

GASTROPODS

Euphemites carbonarius 1½x

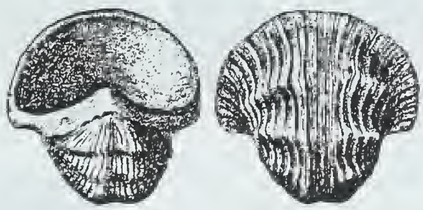
Trepospira illinoisensis 1½x

Donaldina robusta 8x



Naticopsis (Jedria) ventricosa 1½x

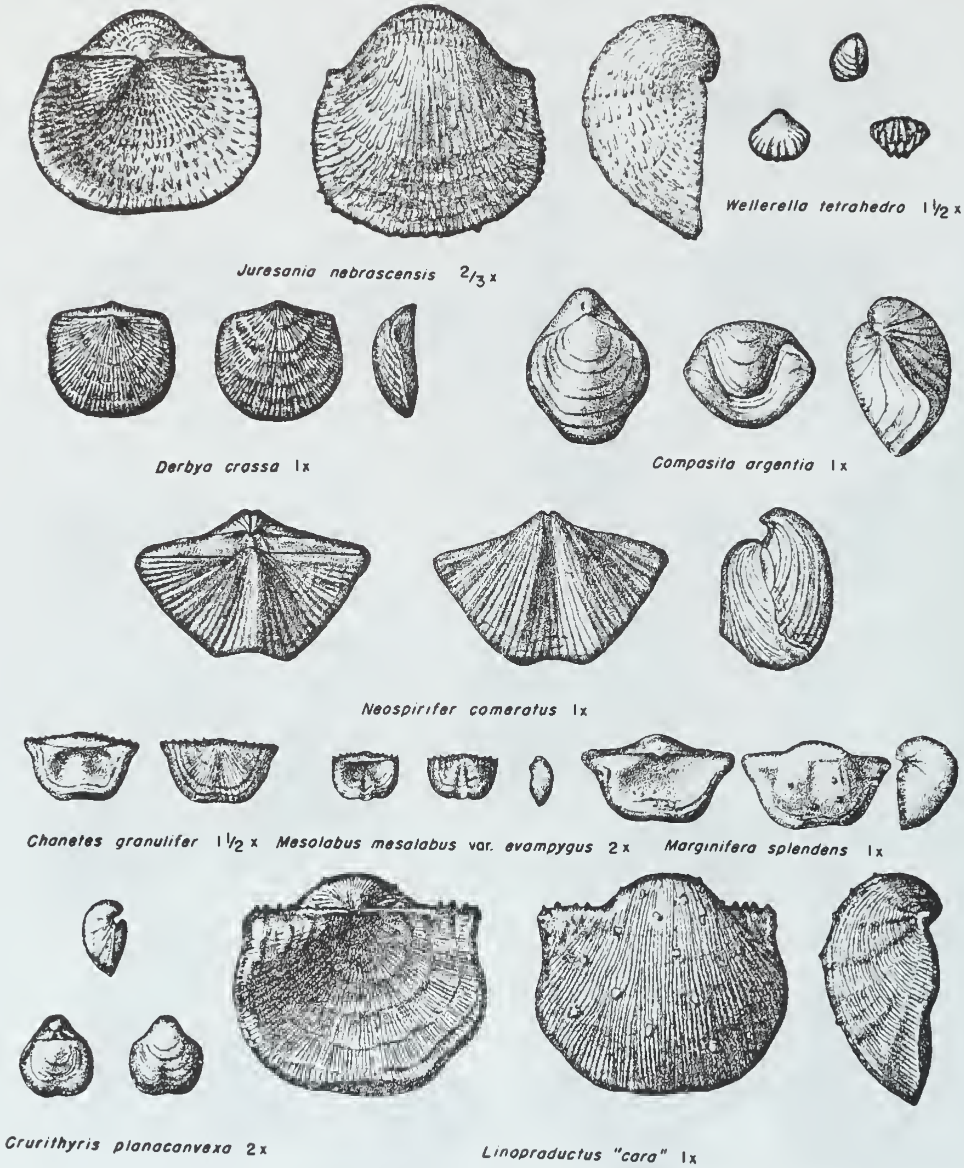
Trepospira sphaerulata 1x

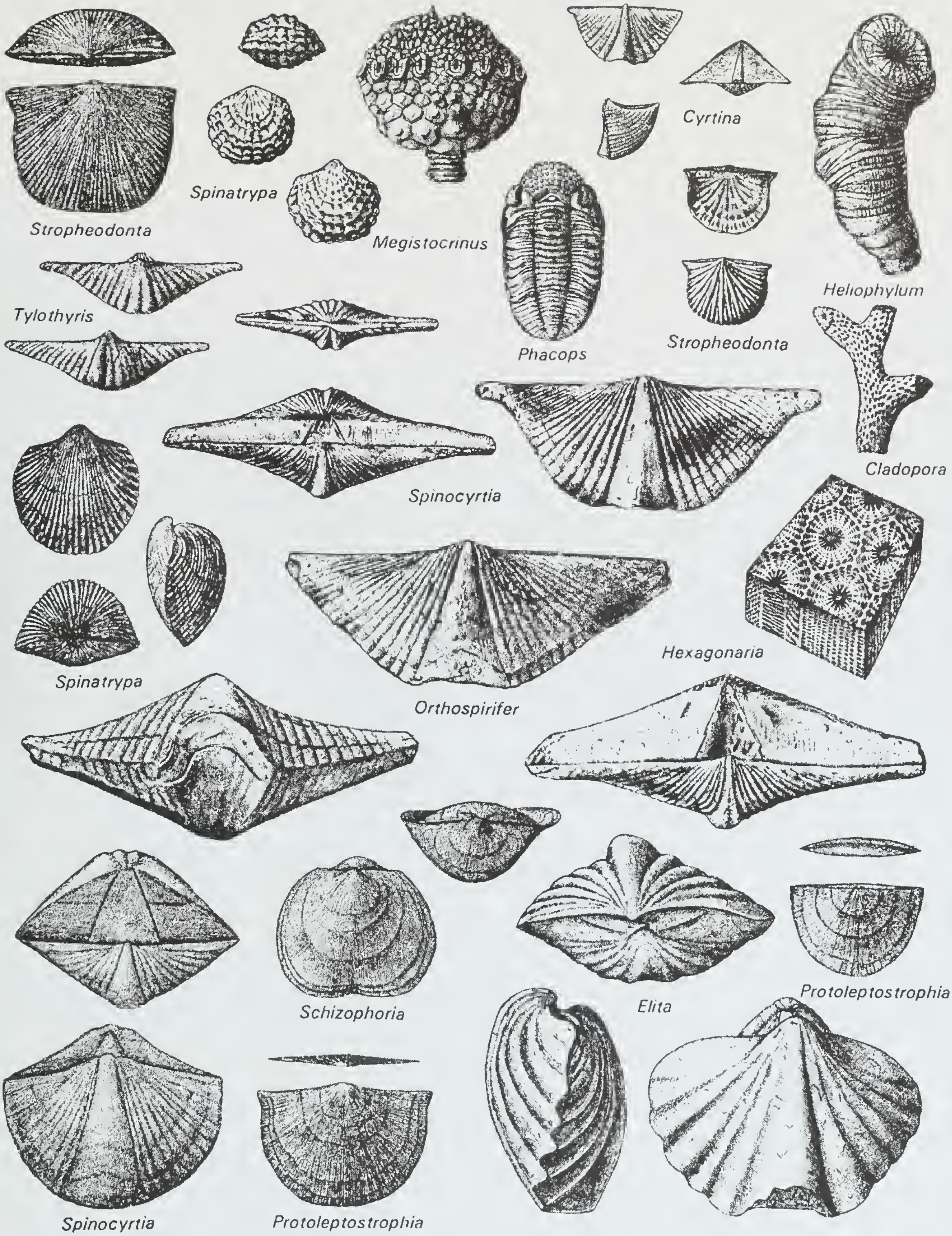


Knightites montfortianus 2x

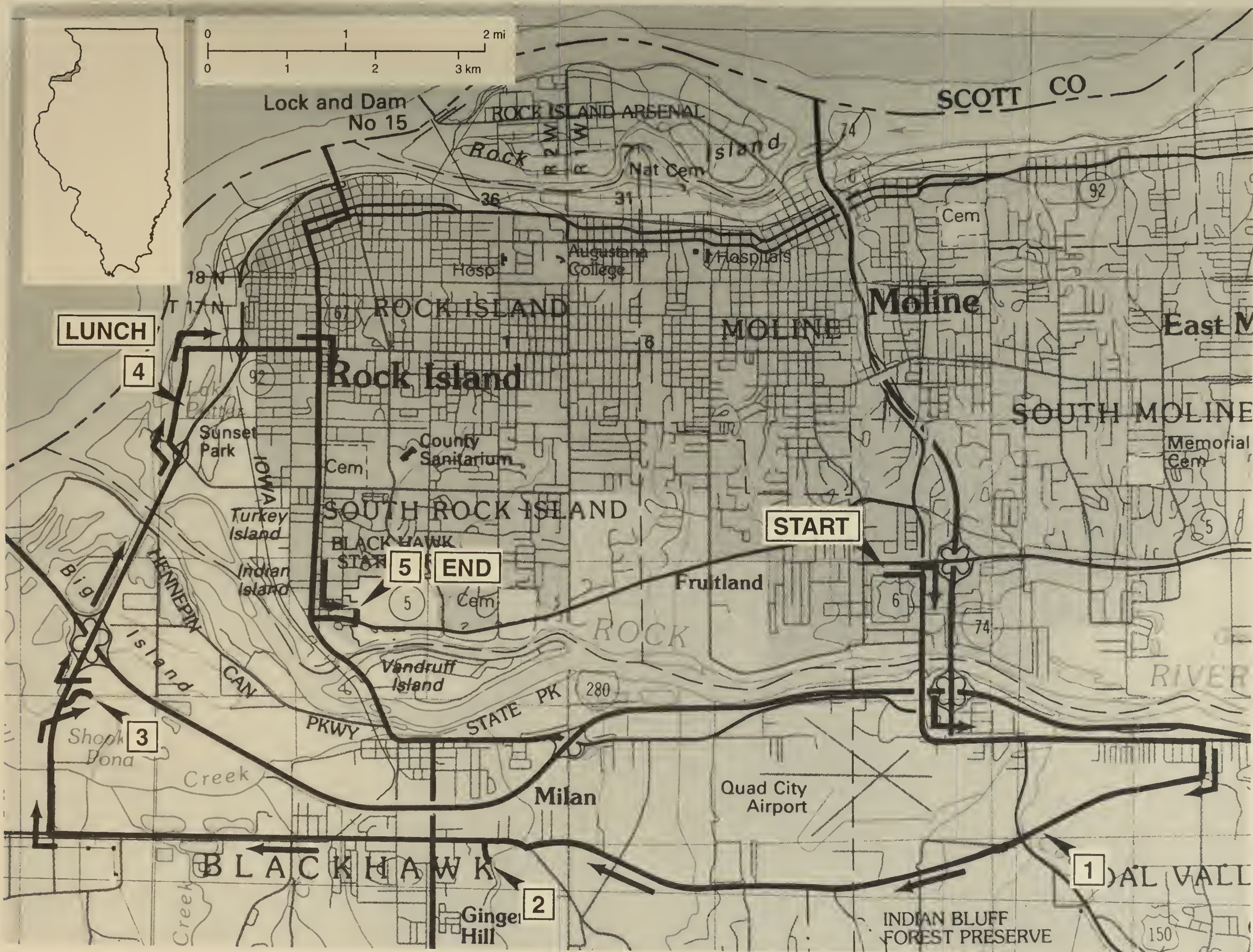
Glabrocingulum (Glabrocingulum) grayvillense 3x

BRACHIOPODS





Devonian Fossils of Northwestern Illinois.



0 1 2 mi
0 1 2 3 km
Lock and Dam No 15
ROCK ISLAND ARSENAL
Rock Island
R 2 W
R 1 W
Nat Cem
SCOTT CO
18 N
T 17 N
LUNCH
4
ROCK ISLAND
Rock Island
Hosp
Augustana College
Hospitals
Moline
MOLINE
East M
SOUTH MOLINE
Memorial Cem
Cem
Sunset Park
IOWA
County Sanitarium
Turkey Island
Indian Island
SOUTH ROCK ISLAND
BLACK HAWK STATE
5
END
START
Fruitland
ROCK
RIVER
Big Island
HENNEPIN CAN
Vandruff Island
PKWY
STATE PK
3
Shook Pond
Creek
Milan
Quad City Airport
BLACKHAWK
2
Ginger Hill
1
AL VALL
INDIAN BLUFF FOREST PRESERVE